A Users Guide to
STANDCARB version 1.0:
A model to simulate the carbon stores in forest stands.

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Introduction

This user's guide describes a new model called STANDCARB that is designed to simulate the dynamics of living and dead pools of carbon in a forest stand. STANDCARB can be used to examine the effects that climate, tree species, succession, wildfire, timber harvest, site preparation, and regeneration success have on carbon dynamics at the stand level. These results are presented in output files that can be used to produce carbon yield tables analogous to volume yield tables (Birdsey 1992). While this model also estimates the mass and volume of boles that are removed by harvest, it does not track the fate of that harvested material. Another model should be used for that purpose (e.g., Harmon et al. accepted) to provide the total stand level carbon balance.

The majority of past models used to examine stand level carbon dynamics have been analytical models (Cooper 1983, Dewar 1991). While these models can be used to analyze many general aspects of carbon dynamics, they have difficulty with complicated or real life situations such as thinning and slash removal. Ecological process models (Cropper and Ewel 1987), while more realistic in terms of ecosystem processes than analytical models, are also limited because they can only simulate a fixed mixture of species. This means that fundamental changes such as species succession or replacement due to silvicultural activity can not be included in these simulations. STANDCARB was designed to overcome these restrictions by incorporating the successional features of a gap simulation model (Urban 1993, Urban et al. 1993) with an ecological process model (Harmon et al. 1990b). It therefore constitues a new type of hybrid model.

Temporally, STANDCARB is a difference model that operates on an annual time step for all variables, except those used to estimate the effects of climate on tree establishment, growth, and decomposition. These climate related variables are calculated on a monthly time step. Spatially, STANDCARB is designed to simulate the dynamics of a number of cells within a stand. Each cell represents the area occupied by a single, mature tree (or an area of approximately 0.04 ha). This approach allows the model to have flexibility in terms of species mixtures and/or tree ages, and allows the user to estimate the degree of spatial variation associated with a simulation. This approach is not designed, however, to simulate the actual location of cells on a landscape.

Because STANDCARB is designed to operate at the stand level, it has incorporated finer levels of resolution within its computations using a meta-model approach. The meta-model approach is used to capture the overall response of more detailed simulation models to a phenomenon without all the computational burdens entailed in including the full model. For example, to simulate species to species interactions, STANDCARB reduces the individual to individual tree interactions found in a gap model to upper and lower tree layers. This allows shade tolerant species to replace shade intolerant species or for tree layers to shade out shrub and herb layers. In a similar manner the penetration of light through foliage is simplified from the detailed individual tree profiles found in gap models to a single layer that removes a fraction of the light depending upon foliage mass. The key point in understanding the use of meta-models is that they capture the key aspects of the behavior of interest, but not all aspects. If the question being asked is the interaction of individuals, for example, then STANDCARB may not be an appropriate model to use.

This users guide is designed to explain how to use the STANDCARB model to investigate the effects of various types of forest management at the stand level on live and dead carbon stores. We first give an overview of the objectives and structure of the model. This is followed by a section that gives examples of the modeling modes that can be used, as well as the features of the output files. The main body of the guidelines contains a summary of each of the major sections of the model, with particular attention to the equations used for critical calculations. Finally, the types and structures of the input and output files are defined.

Before using the model a final word of caution is in order. STANDCARB is a simulation model. As such it represents our best representation of reality, but the results must be used with caution. There are many factors that may cause the projected results to deviate from what actually occurs. This is no different than the distinction between volume yield projections and the actual harvested volume. Bear in mind each simulation has a number of tacit assumptions, and when these are not met the projected results may be entirely misleading. For example, we assume that pathogens do not removed a significant amount of carbon, but in some stands this is not the case. It may also be the case that the simulations are correct in a relative sense but not in an absolute sense. When interpreting results bear in mind that relative differences will always be more robust than absolute differences. Finally, it must be kept in mind that simulation models are only tools to be used primarily for planning or understanding how a system works. They are not a substitute for actual measurements of the actual forest carbon stores of particular stand.

Model Overview

OBJECTIVES

The object of STANDCARB is to simulate the accumulation of carbon over succession in mixed species, mixed aged forest stands. This version of the model is parameterized for stands in the Pacific Northwest. There is no reason, however, that it could not be used for other types of forests as well. The model can be used to investigate the stand level effects of various regeneration strategies, effects of thinning, patch cutting, tree species replacement by design or by natural succession, site preparation, and wildfires.

The model provides output on seven live state variables, nine "dead" state variables, and three variables related to the volume harvested (see Output files section for more details). The state variables are saved as means and standard errors of the mean for each year. Values for each cell for each year are deliberately not saved because the model is not designed to spatially distribute results over a landscape. In other words, STANDCARB is not a landscape model, although it can be used to estimate the degree of variation within a stand.

BASIC APPROACH

The approach used in STANDCARB is to utilize the features of a gap model to simulate species composition and the structure of an ecosystem "process" model to simulate the growth, mortality, and decomposition of plants within a plot. As with gap models, a simulation run does not consist of single plot, rather a stand is simulated by running many replicate plots or cells which are then averaged to predict stand level values. If one chooses to use the single cell mode, the model is reduced to the approach of a typical ecosystem model.

STANDCARB has a number of levels of organization that it uses to estimate changes in carbon stores within a stand (Figure 1). At the highest level there are a number of **cells**, each which contains up to four **layers** of vegetation, six detrital pools and a stable soil carbon pool. The four layers of vegetation that can occur in each cell are upper trees, lower trees, shrubs, and herbs. The two tree layers can have different species, whereas the shrub and herb layers are viewed as single "species". Each cell can have any combination of layers except that lower trees can only occur when upper trees are present.

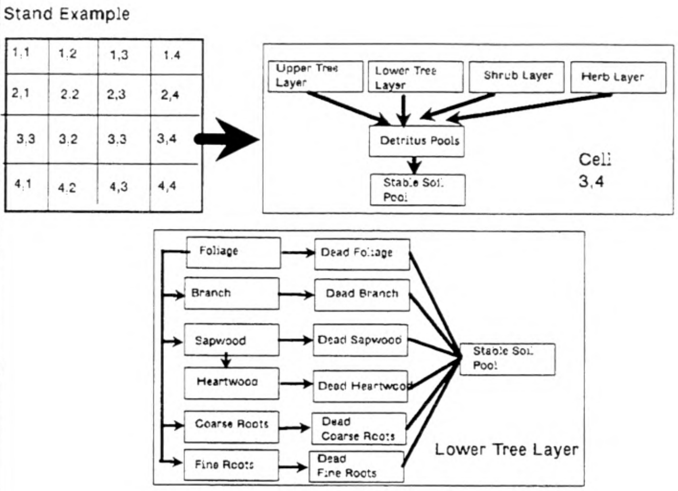

Figure 1. Overall conceptual structure of STANDCARB

Each of the layers can potentially have six live **parts**: 1) foliage, 2) fine roots, 3) branches, 4) sapwood, 5) heartwood, and 6) coarse roots. Of course to make the layers correspond to the actual structure of certain life forms, herbs are restricted from having woody parts and shrubs can not have sapwood and heartwood (as they do not form a bole). All the live parts correspond to parts typically reported in the ecological literature with the exception of the bole. The later would be composed of the sapwood and heartwood parts. In our model heartwood includes the heartwood and the outer bark as these are non respiring, decay resistant layers. The sapwood includes the sapwood and the inner bark layers as these are respiring and decompose relatively quickly compared to outer bark or heartwood.

Each of the live parts of each layer contributes material to a corresponding detrital or dead **pool**. Thus foliage adds material to the dead foliage, fine roots to dead fine roots, branches to dead branches, sapwood to dead sapwood, heartwood to dead heartwood and coarse roots to dead coarse roots. Rather than have every plant layer in each cell have its own detrital pool, we have combined all the inputs from the layers of the cell to form a single detrital pool for each plant part. For example, the foliage from the four plant layers feeds into a single dead foliage pool. Another simplifying step is to model pools regardless of their position or location in each cell. This avoids having a suspended or buried subgroup for each detritus pool. This means that dead fine roots can occur in the mineral or inorganic soil layers, or that dead branches includes suspended or downed fine wood. We are therefore assuming that by using an aggregated rate of decomposition for these pools, we can capture the majority of the systems dynamics.

There is not a one to one correspondence of the detrital pools to those typically reported in the literature. This is because various contradictory sampling schemes have been used in the past field studies. The detrital pools modeled in STANDCARB are generally finer divisions than one might find in carbon inventories. The typical forest floor measured would usually include the dead foliage, some of the dead fine roots (depending upon the ecosystem in question), and some of the dead branches. Fine woody debris would correspond to the dead branch pool and coarse woody debris would correspond to the dead sapwood and heartwood pools. Dead coarse roots are rarely inventoried, but would match the modeled pool with that name.

Finally, all the detritus pools in a cell can potentially add material to a stable soil pool. As with the detrital pools, we model this regardless of location because the objective is to simulate a pool of highly decomposed material that changes slowly and is quite resistant to decomposition. Although many of the detrital pools can form this type of material, we have set the default parameters to only have dead fine roots and dead coarse roots to contribute to this pool. Therefore the stable soil pool will generally correspond to the mineral soil pool in most inventories. If flows from other detrital pools are included, then inventory categories need to be changed as well.

COMPUTING ENVIRONMENT

STANDCARB can currently be run in either a WINDOWS, or UNIX environment. It is also possible to run the model in a DOS environment. The computing environment that is used will make a slight difference in the output from a given simulation run, even when the random number sequences are the same. These differences, however, are relatively small and within 2% of the mean of many runs.

MODEL MODULE OVERVIEW

STANDCARB consists of a number of modules which perform specific functions (Figure 2). The following section describes the general purpose of each module. A fuller description of each can be found under the Model Documentation section.

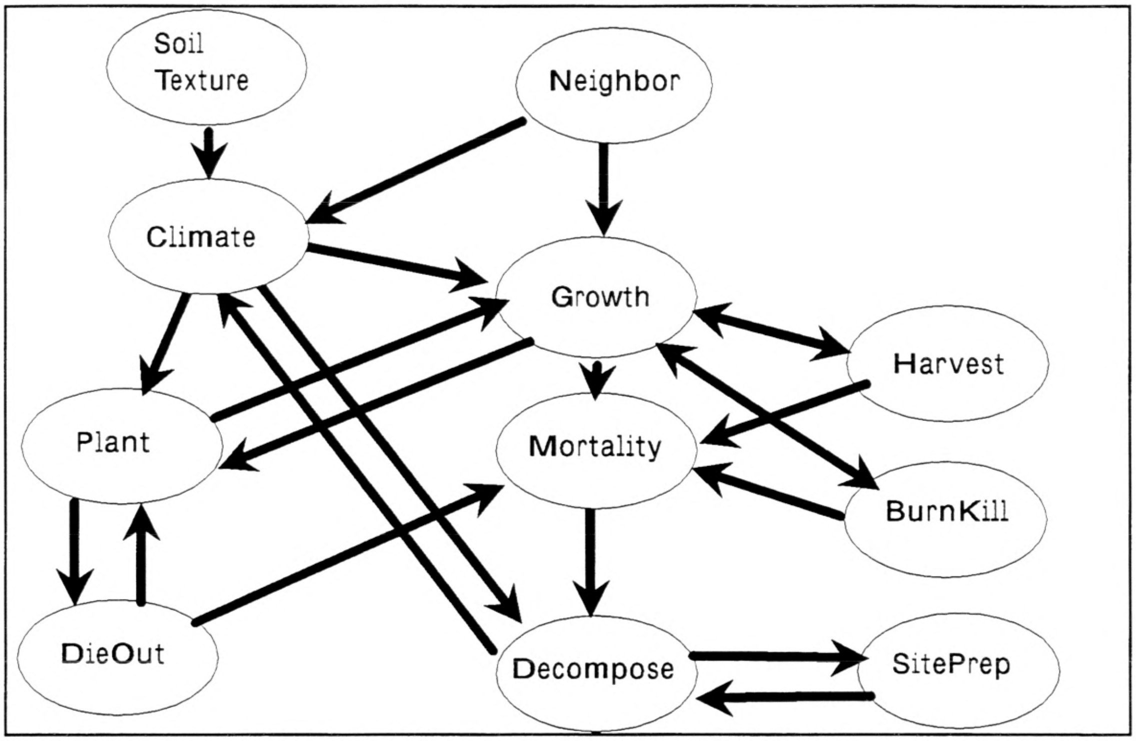

Figure 2. Modules of the STANDCARB model and flow of information.

CLIMATE. The purpose of this module is to determine the effect of climate on tree species, growth, and decomposition.

SOIL TEXTURE. This module is used to calculate the effects of soil texture, depth and rockiness on the water holding capacity of soils. This information is passed on to the CLIMATE module.

PLANT. This module determines which layers and tree species can be planted in a cell. Herb and shrub layers are planted into each plot based on a fixed probability depending on the presence of a tree layer. The upper tree layer is planted before the lower tree layer. If a tree layer is planted, this module also determines which species will establish. The probability of a tree species colonizing a site is a function of shade tolerance, temperature, and moisture limits and the local abundance of a species in a life zone.

DIEOUT. The purpose of this module is to determine if the upper tree layer will completely dieout in a plot. The basic idea is that above a certain tree age, each cell is dominated by a single tree. When this tree dies, the underlying tree layer grows faster and replaces the old upper tree layer. This in turn allows the establishment of new lower tree layer. Combined with PLANT, the DIEOUT module allows STANDCARB to simulate species replacement during succession.

GROWTH. This module determines the rate that living plant parts grow in a cell. The living parts tracked by the GROWTH objects include foliage, branches, sapwood, heartwood, coarse roots, and fine roots. In addition to these six plant parts, this module computes the total live mass and the live bole volume. The rate of growth is dependent upon the amount of foliage within a cell and the maximum rate of net production as determined by the CLIMATE objects. The growth of foliage for each layer is dependent on its light extinction rate and light compensation point.

MORTALITY. The function of this module is to determine the rate of detrital production when a plot has not been harvested or burned. For foliage and fine roots, a fixed proportion is assumed to die each year. These proportions will be functions of the species (e.g., deciduous trees and herbs lose all their leaves each year). The proportion of boles, branches, and coarse roots lost to mortality or pruning is a function of the light environment, as calculated in GROWTH, so that as the light passing through the foliage of a layer approaches the light compensation point, the mortality rate reaches a maximum.

DECOMPOSE. This module determines the balance of inputs from normal mortality, harvesting and fires and the losses from decomposition and fire. These balances are calculated for each of the six detrital pools (dead foliage, dead fine roots, dead coarse roots, dead branches, dead sapwood, and dead heartwood) and a stable soil pool. In addition to these 7 pools, this module calculates the total detrital (excludes stable soil matter) and the total dead stores. The MORTALITY, HARVEST, and BURNKILL modules are used to calculate detritus inputs. The rates of decomposition of each pool are determined by the species contributing detritus to a cell, and climatic effects as calculated in the CLIMATE module. Losses from fires are determined by the SITEPREP module.

HARVEST. This module determines if the plot is to be harvested, and the amount of live plant parts removed from the forest and the amount added to detrital pools. Types of harvest simulated are precommercial thinning, commercial thinning, and clear-cut harvest. Each of these harvest types can be conducted in a subset of the cells or in all the cells. For each simulation, the user can set three levels of utilization standards where the amount cut and removed can be specified. Only sapwood and heartwood (i.e., boles) can be removed from the simulated forest. All other living pools (leaves, branches, fine roots, and coarse roots) are transferred to the appropriate detrital pools.

SITEPREP. This module determines the effect of site preparation following harvest on detrital pools. Three levels of detrital reduction can be specified in each simulation run. This module is also used to determine the effects of wildfires.

BURNKILL. This module is used to determine the amount of the living layers that is killed by site preparation fires or by wildfires. As with SITEPREP, three levels of fire severity can be specified in each simulation run.

NEIGHBOR. The purpose of this module is to determine the overall light environment of a cell and the interaction with neighboring cells. The degree of blocking of direct and diffuse light is determined by the relative tree and topographic height of cells. Height of the upper tree layer is a function of the age of that layer in a cell.

Example Simulations

The following section illustrates features of the STANDCARB model using output from selected simulations. The model output files (i.e., ascii text format) were imported into a graphics software to produce the figures. Note that these figures are for illustrative purposes only and should not be used to estimate real carbon balances!

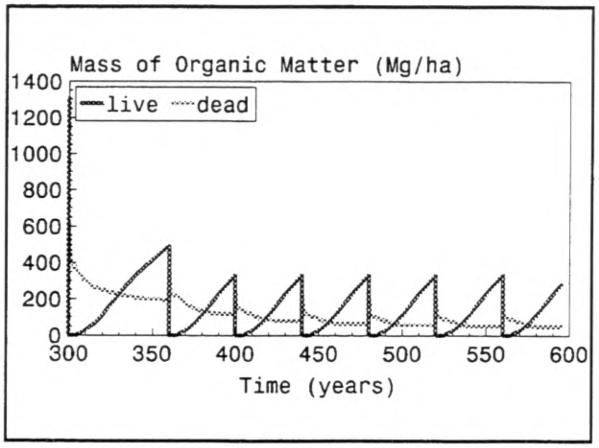

Figure 3. Hypothetical change in live and dead organic matter stores for an old-growth Douglas-fir forest that is harvested and then clearcut harvest every 40-60 years.

COMPARING SILVICULTURAL STRATEGIES

The primary purpose of the STANDCARB model is to allow the user to compare the effect of various types of silvicultural treatments on carbon stores in forest ecosystems. For example, one might want to compare the effect clearcutting on a 40-60 year rotation (Figure 3) to a system in which stands are thinned every 10 years (Figure 4). These particular figures were produced for using the single cell version of the model and would be typical of a Douglas-fir forest of medium productivity. The results shown indicate the trend after a 300 year calibration period. The preliminary indication would be that the frequently thinned silviculture plan would, averaged over the 300 years of simulated treatments, store twice the organic matter of the clearcut scenario.

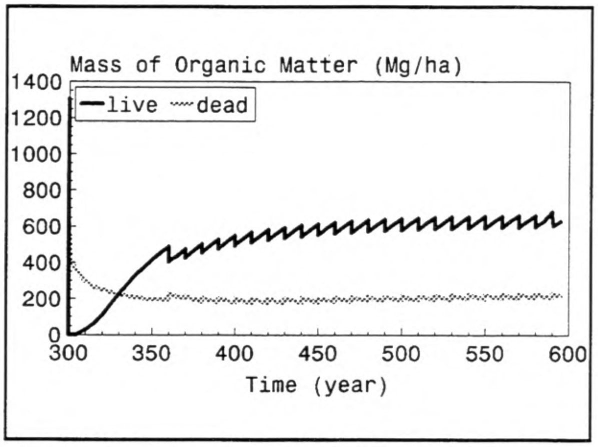

Figure 4. Hypothetical change in live and dead organic matter stores for an old-growth Douglas fir forest that is clearcut harvested and then subjected to a 10% thinning every 10 years.

SINGLE CELL VERSUS MULTICELL VERSIONS

Although the single cell version of STANDCARB can be used to give a fast, preliminary idea of how a silvicultural treatment will store carbon, there are several advantages to using the multicell version of the model. The first is that species mixtures are allowed to change over time in the multicell version. In the examples given above (Figures 3 and 4), it is likely that Douglas-fir would be replaced by a more shade tolerant species (e.g., western hemlock) under the frequent thinning scenario. This might lead to unanticipated changes in carbon stores if the growth, mortality, or decomposition parameters of the replacement species differ from Douglas-fir.

Unfortunately, in the single cell version the species are fixed. This can be overcome by using the multicell version, however. The results of these two versions are quite similar when the species in the upper and lower tree layers for both versions are the same (Figure 5). Note that the multicell results are near the single cell results, but sometimes are higher and lower.

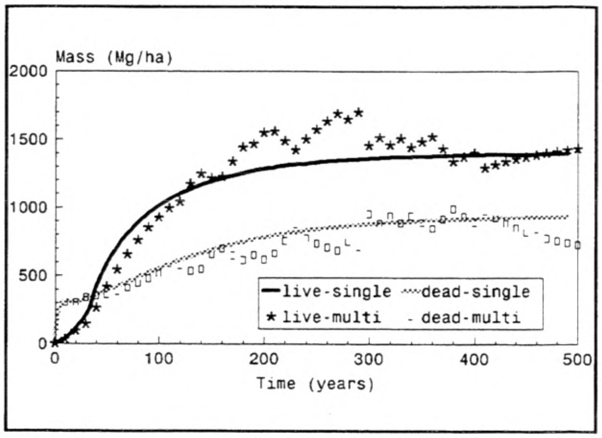

Figure 5. Comparison of the single cell version of STANDCARB to the multicell version when the species are the same.

VARIATION IN THE MULTICELL VERSION OF STANDCARB

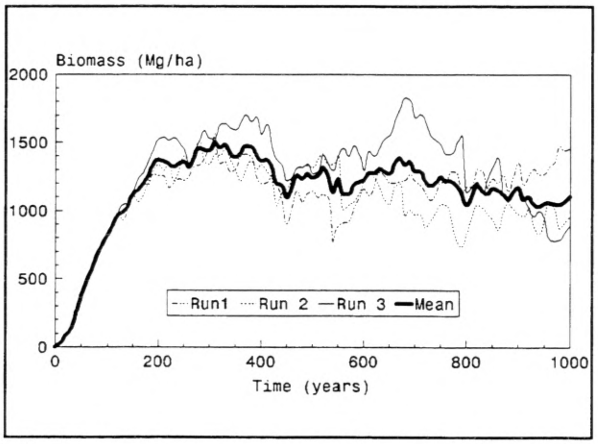

Figure 6. Long-term trend in live biomass generated by the multicell version of STANDCARB. Each run is a separate simulation; the mean is the average of these runs.

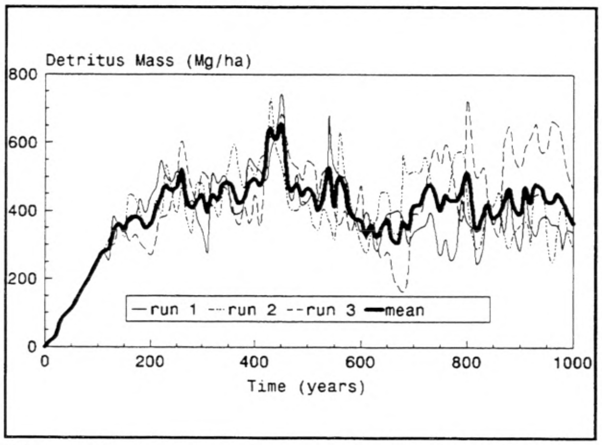

Figure 7. Long-term trend in dead or detritus stores predicted from the multicell version of STANCARB. Runs and means are as in Figure 6.

An important aspect of the multicell versionis that it is stochastic. That is, when the model is run in this mode and given a new random number seed, it will produce a slightly different output each run (Figures 6 and 7). This element of "randomness" is a key feature during forest development and important to recognize. By using the multicell version of the model and running a scenario with a new random number seed each time, one can generate "data" to test effects of treatment using statistics such as analysis of variance. Even if one does not wish to use statistics to test the outcome of the experiments it is still important to run the model at least 3 times to get an average response. Notice that in Figures 6 and 7 that each run generally parallels the mean value, but there are times when individual runs are quite a bit higher or lower than the mean. As an aside, the downward trend in both live and dead stores after 400 years is due to the replacement of Douglas-fir by western hemlock predicted by the multicell version. This indicates the single cell version, while matching the early phases of succession is correct, fails to predict the overall decline in carbon stores caused by species replacement.

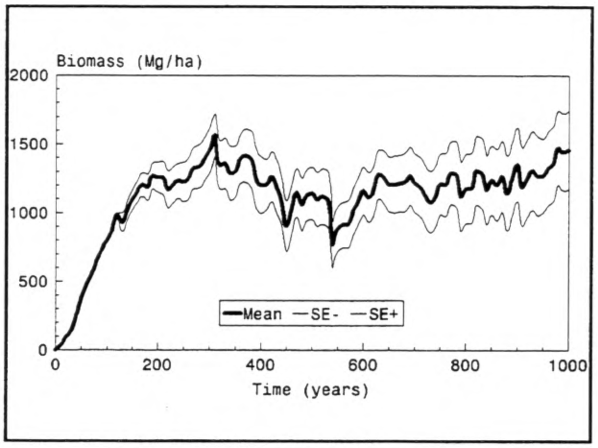

Figure 8. Mean plus and minus one standard error of live biomass plotted over time. Note that the standard error is for one simulation and represents the degree of internal variation in the simulated stand.

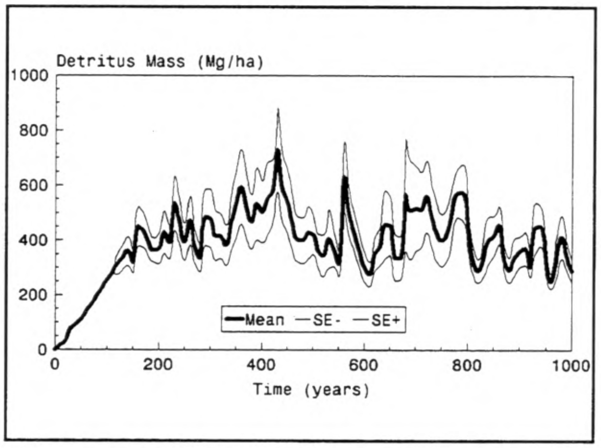

Figure 9. Mean plus and minus a standard error for dead or detrital stores over time. The standard error reflects the internal variation in the simulated stand.

Another feature of the multicell version of the model is that the internal variation of the stand being simulated can be computed (Figures 8 and 9). Internal variation is an important part of the multicell version and enters the simulation because cells can be colonized at different times by different species and/or the upper tree layer in cells can be replaced by lower trees at different times. This reflects the patchiness of a real forest, which of course is not the homogenous tree layer assumed in the single cell version. For most of the output files, the mean as well as the standard error of the mean is computed. Figures 8 and 9 were prepared by adding and subtracting one standard error of the mean from the mean value. The value of plotting the data in this manner is that one can use a single simulation to estimate how much variation to expect if another simulation (using another random number seed) was run. Notice that the variation about the mean increases with time in these figures, indicating that the formation of tree gaps caused by upper trees dying is causing the greatest amount of variation. Plotting the standard errors of single cell version is not the same as plotting multiple runs, however. Therefore averaging several runs is the soundest strategy to assess the effect of a silvicultural treatment.

INTERACTIVE VERSUS NONINTERACTIVE MODE

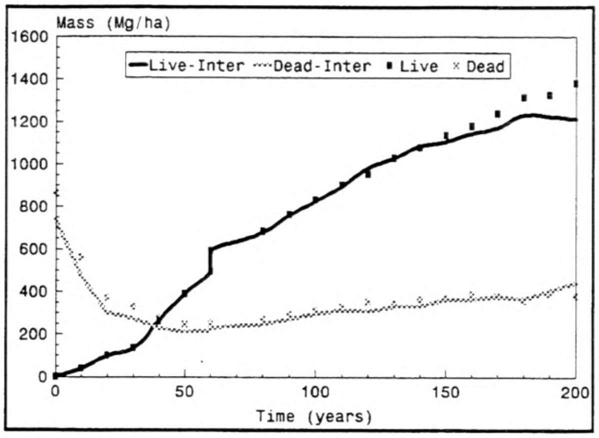

Figure 10. Comparison of the interactive (live-inter and dead-inter) versus the noninteractive modes of STANDCARB for stands that were completely clear-cut and allowed to grow 200 years.

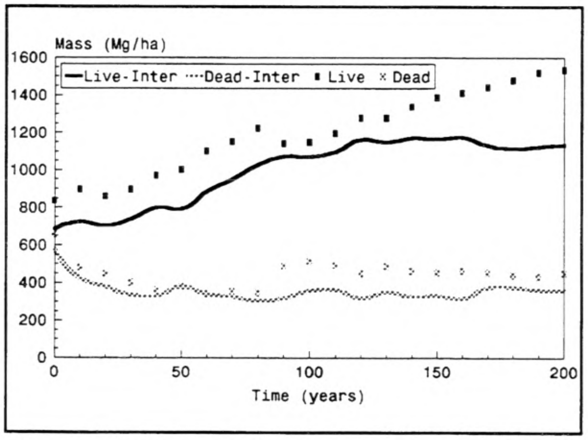

Figure 11. Comparison of interactive and noninteractive modes of the STANDCARB model for an old-growth forest that was clearcut in a checkerboard pattern .

Within the multicell version of the STANDCARB model it is possible to run simulations that have the cells act independently (noninteractive mode) or to have the cells interact through shading. The latter mode is probably the most realistic, in that it allows cells with larger trees to shade cells with smaller trees. This might be important if a species, such as Douglas-fir, requires a certain sized opening to regenerate. In the non-interactive mode shade intolerant species might be able to replace themselves, however, when one cell can shade another this might not be the case. Just because the interactive model is the most realistic does not mean it will always give different results than the noninteractive mode. For example, if the entire stand is clear-cut the two modes give very similar results for at least 200 years after clearcutting (Figure 10). This is because even though the cells interact, the tree height differences are minimal. This is in contrast to a checkerboard cutting patterns in which every other cell is clearcut. In this case, the differences in tree heights between cells is maximized and the difference between the two modes is quite striking (Figure 11). Notice that the interactive mode has less carbon stores than the noninteractive mode. This is because the larger trees are limiting the growth of the smaller trees. The importance of interactions is also evident when half a stand is cut and the other half remains unharvested. Here we find that, after 100 years, the live carbon is substantially less in the interactive mode than in the noninteractive mode (Figure 12). This indicates that although there are interactions, they take period to have an effect on carbon accumulation. The key point to remember when trying to decide between the non- and interactive modes is that the more intricate the cutting pattern, the more likely interactions between cells will influence the results. This must be balanced against the fact that the interactive mode is computationally more demanding and will take longer to run.

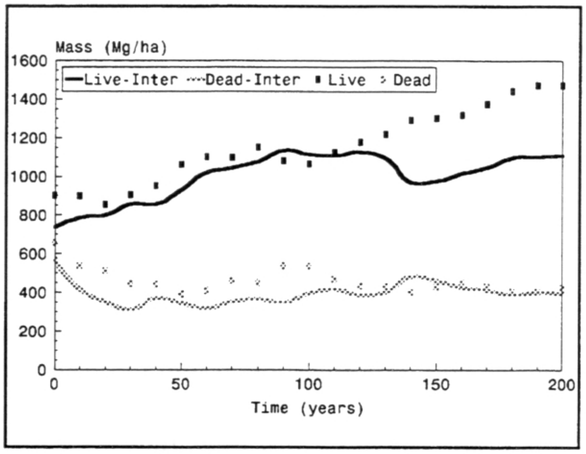

Figure 12. Comparison of interactive and noninteractive modes of STANDCARB when half of an old-growth forest is cut and half remains uncut. In contrast to the checkerboard pattern the cut was in a large single block.

Model Documentation

This section describes each of the main model modules in detail. For each of the model modules we describe the overall purpose, the functions it contains as well as the computations used and the logic behind them, and the input data and parameters required.

STANDCARB is programmed to compute changes in state variables at the cell, layer, part, and pool level depending upon the desired level of resolution. Rather than describe each of these levels, we have tried to describe the level that pertains to all the underlying levels. For example, the equation describing the balance of inputs and losses for all detrital layers is the same regardless of the cell number, species, layer, or detrital pool involved. We have therefore described this equation generically in the documentation, although in the actual computer source one will find the variable completely specified.

The following naming conventions are used throughout this section:

1) All model modules are indicated by full capitalization of the name (e.g., CLIMATE).

2) All variables, parameters and state variables are indicated with capitalized letters for each significant part of a name (e.g., DeadBranch, TempOpt). An advantage of using C++ for programming is that variable names can be longer than 6 or 8 characters. We have made the names as long as needed to describe a variable, in many cases stringing together entire words.

3) In cases where a variable or parameter could pertain to more than one living **layer** plant **part**, or detrital **pool**, we have added the name of that layer, part, or pool to make the overall name (e.g., DeadBranchTempOpt).

4) When we are referring to a general set of calculations for all the living layers or detrital pools we have added *Layer, Part,* or *Pool* to make the overall name (e.g., *Pool*TempOpt).

5) There are also a number of variables that apply to different time steps. We have therefore used the prefix *Mon* for those calculated monthly, *Total* for those summed over a year, and *Annual* for those averaged over a year.

Model Modules

CLIMATE

The purpose of CLIMATE is to estimate the effect of temperature, precipitation, and radiation on the establishment of tree species, growth of plants, and decomposition of detritus. The data used to drive these estimates are found in the Climate.drv and Locate.drv files.

This module contains 15 functions. The TempConvert and DegreeDays are calculated once at the start of each simulation and used for all the cells in a stand. The functions that estimate interception (CanInterception, LogIntercept, ForFloorInterception, and Total Interception), water stores (PET & Transpire, WaterStore, and WaterPot), the effects of climate on decomposition (MoistDecayIndex, TempDecayIndex, and AbioticDecayIndex) as well as growth (TempProdIndex, MoistProdIndex, and ProdIndex) are calculated each month on each cell. The variables calculated have differing prefixes depending upon the time step used and whether they are annual averages or totals. Variables calculated on a monthly time step have the prefix *Mon*. If month is used in a generic sense we have italicized the prefix. Variables that are averaged over the year have the prefix Annual, and those that are yearly totals have the prefix TotalAnnual.

The variables calculated in this module is used by PLANT, GROWTH, and DECOMPOSE modules. To keep the time step the same as used in these modules the output information has been converted to annual means or summaries depending on the variable.

TempConvert Function

This function converts mean daily temperature based on a 24 hour period into the mean day time temperature required by the TempProdIndex function. The daily (24 hour) mean temperature is converted to the mean daytime temperature using the mean monthly 24 hour temperature (Temp24) and the mean maximum temperature (TempMax):

$$\mathit{Mon}\text{TempDay} = 0.212 * (\mathit{Mon}\text{TempMax} - \mathit{Mon}\text{Temp24}) + \mathit{Mon}\text{Temp24}$$

where *Mon*TempDay is the daytime temperature.

For the purposes of computing the respiration losses of living plant parts, the mean annual temperature (MeanAnnualTemp) is computed from the *Mon*Temp24 values.

DegreeDays Function

This function computes the degree days for the site. This is computed once per simulation run. The degree days (DDays) is the sum of all temperatures for all the days exceeding 5.56 C. To compute DDays we first compute the mean daily temperature from the mean monthly values stored in the CLIMATE.drv file. This is done by linearly interpolating between the midpoint of each month. The daily change in temperature between each month is:

$$\text{TempChange}\mathit{Mon}1=\text{Temp24}\mathit{Mon}2-\text{Temp24}\mathit{Mon}1/\text{Julian}\mathit{Mon}2-\text{Julian}\mathit{Mon}1$$

where these are the daily temperatures (Temp24) for the respective months and the Julian day of the midpoint of months 1 and 2. Given the daily rate of change, the Julian day, and the mean monthly temperature, the daily temperature (TempDaily) is computed:

$$\text{TempDaily}=\text{Temp}\mathit{Mon}1+\text{TempChange}\mathit{Mon}1*(\text{Julian}-\text{Julian}\mathit{Mon}1)$$

where Julian is the Julian day, and the other variables are as defined above. The total degree days is then computed by adding all the temperatures of the days exceeding 5.56 C.

CanInterception Function

This function calculates the amount of canopy throughfall based upon the mean monthly precipitation and the mass of foliage as calculated in GROWTH. Each layer occupying a cell is capable of intercepting precipitation. The canopy interception of each layer increases linearly with increasing foliage mass at a rate defined by the parameter *Layer*CanIntCst in the GrowParm.prm file. The proportion of precipitation intercepted by foliage of all the layers in a given year and cell is:

$$\text{CanInterRate}=\sum(\mathit{Layer}\text{CanIntCst}*\mathit{Layer}\text{Foliage})$$

where *Layer*Foliage is the mass of foliage for a particular layer in a cell. Canopy throughfall is the fraction of the precipitation that is not intercepted by the canopy:

$$\mathit{Mon}\text{CanThroFall}=\mathit{Mon}\text{Precip}*(1-\text{CanInterRate})$$

where *Mon*CanThroFall is the amount of precipitation allowed to pass through the canopy each month and *Mon*Precip is the mean monthly precipitation as defined by the Climate.drv file. The amount of precipitation intercepted each month is given by:

$$\mathit{Mon}\text{CanInterception}=\mathit{Mon}\text{Precip}*\text{CanInterRate}$$

LogIntercept Function

This function estimates the amount of interception from dead sapwood, dead heartwood, dead branches, and stumps as a function of their mass as calculated in DECOMPOSE (Figure 13). It also adjusts the interception as a function of the maximum moisture content of the woody material.

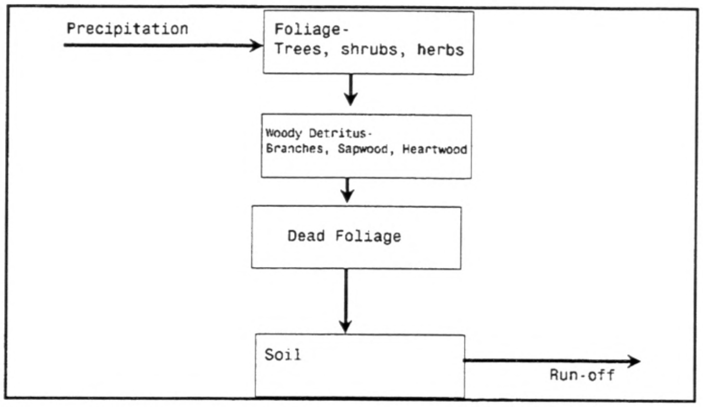

Figure 13. Interception and stores of water

The first step is to calculate the projected area of each dead wood pool from its mass:

$$\textit{Pool}\text{ProArea}=\textit{Pool}\text{AreaMassRatio}*\textit{Pool}/100$$

where *Pool*ProArea is the projected area in percent of the cell surface area, and *Pool*AreaMassRatio is the ratio of projected area to mass of the woody detrital pool. The latter parameters are found in the DcayParm.prm file. Pool can be either DeadSapwood, DeadHeartwood or DeadBranches.

The next step is to calculate the amount of *Mon*CanThroFall intercepted by the woody detrital pools. The amount intercepted is a function of the maximum potential interception based on area (MaxPotInterceptionArea) and the maximum potential based on the storage capacity (MaxPotInterceptionCap). The maximum potential interception based on area is:

$$\text{MaxPotInterceptionArea}=\textit{Pool}\text{ProArea}*\textit{Mon}\text{CanThroFall}$$

where *Pool*ProArea is the projected area of a pool and *Mon*CanThroFall is the monthly canopy throughfall as calculated above. The maximum potential based on the storage capacity (MaxPotInterceptionCap) is calculated first by calculating the maximum storage capacity of the woody detritus pool:

$$\text{MaxStoresCap}=\text{StoresMax}-\text{StoresAct}$$

where the maximum possible water store is:

$$\text{StoresMax}=\textit{Pool}*\textit{Pool}\text{MoistStoreMax}/100$$

where *Pool*MoistStoreMax is set in the DecayParm.prm file. The actual current water stores is:

StoresAct=*Pool***Mon*PoolMoist/100

where *Mon*PoolMoist is calculated by the CLIMATE WaterStore function. The maximum potential interception based on storage capacity is:

MaxPotInterceptionCap=MaxStoresCap/100

assuming there are 100 Mg/ha of water in 1 cm of precipitation.

The amount of canopy throughfall (MonCanThroFall) intercepted by the woody detritus pools depends on the relationship of the maximum potentials based on area and storage capacity. If MaxPotInterceptionArea is less than or equal to MaxPotInterceptionCap then:

*MonPool*Inter=MaxPotInterceptionArea

If, on the other hand, MaxPotInterceptionArea is greater than MaxPotInterceptionCap, then:

*MonPool*Inter=MaxPotInterceptionCap

This relationship assures that the detritus pool can not absorb more water than the detritus pool can store. The last step is to calculate the amount of canopy throughfall that is passed on to the forest floor. The amount added to the forest floor each month as log throughfall is:

*Mon*LogThroFall= *Mon*CanThroFall-*Mon*DeadSapwoodInter-*Mon*DeadHeartwoodInter
-*Mon*DeadBranchInter

The total interception by the dead woody pools is:

*Mon*LogInterception = *Mon*DeadSapwoodInter+ *Mon*DeadHeartwoodInter
+*Mon*DeadBranchInter

ForFloorInterception Function

This function estimates the amount of interception by the dead foliage pool (DeadFoliage) as a function of the mass as calculated in the Decomposition function and the maximum moisture content of this detrital pool.

We assume that until a certain mass, the dead foliage does not cover the cell surface completely. If DeadFoliage is less than or equal to 5 Mg/ha, the projected area covered by dead foliage increases linearly with mass:

DeadFoliageProArea=DeadFoliageAreaMassRatio*DeadFoliage/100 where DeadFoliageProArea is the projected area of dead foliage and DeadFoliageAreaMassRatio defines the relationship between mass and projected area as defined in the DcayParm.prm file. If on the other hand the dead foliage mass exceeds 5 Mg/ha then

DeadFoliageProArea=1.0

The amount intercepted by the dead foliage pool each month is a function of the maximum potential interception based on area (MaxPotInterceptionArea) and the maximum potential based on the storage capacity (MaxPotInterceptionCap). The maximum potential interception based on area is:

MaxPotInterceptionArea=DeadFoliageProArea**Mon*LogThroFall

where *Pool*ProArea is the projected area of a pool and *Mon*LogThroFall is the monthly log throughfall as calculated above. The maximum potential based on the storage capacity (MaxPotInterceptionCap) is calculated first by calculating the maximum storage capacity of the woody detritus pool:

MaxStoresCap= StoresMax- StoresAct

where the maximum possible water store is:

StoresMax=DeadFoliage*DeadFoliageMoistStoreMax/100

where DeadFoliageMoistStoreMax is set in the DecayParm.prm file. The actual current water stores is:

StoresAct=DeadFoliage**Mon*DeadFoliageMoist/100

where *Mon*DeadFoliageMoist is calculated by the CLIMATE WaterStore function. The maximum potential interception based on storage capacity is:

MaxPotInterceptionCap=MaxStoresCap/100

assuming there are 100 Mg/ha of water in 1 cm of precipitation.

The amount of log throughfall (MonLogThroFall) intercepted by the dead foliage pool depends on the relationship of the maximum potentials based on area and storage capacity. If MaxPotInterceptionArea is less than or equal to MaxPotInterceptionCap then:

*Mon*DeadFoliageInterception=MaxPotInterceptionArea

If, on the other hand, MaxPotInterceptionArea is greater than MaxPotInterceptionCap, then:

*Mon*DeadFoliageInterception=MaxPotInterceptionCap

This relationship assures that the dead foliage pool can not absorb more water than it can store.

The amount added to the soil as throughfall from the dead foliage pool each month is:

*Mon*DeadFoliageThroFall=*Mon*LogThroFall-*Mon*DeadFoliageInterception

Total Interception Function

This function calculates the total amount of precipitation intercepted by the canopy, above-ground dead woody detritus pools, and the dead foliage pool (Figure 14). The monthly total interception is:

*Mon*TotalInterception=*Mon*ForFloorInterception+*Mon*LogInterception
+*Mon*CanopyInterception

TotalAnnualInterception is the sum of all the monthly interception values.

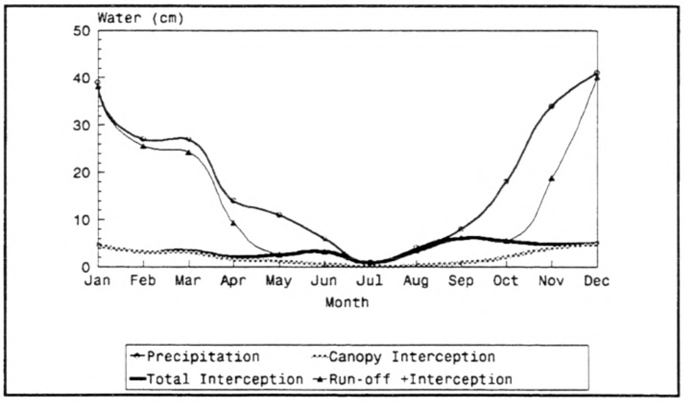

Figure 14. Example of seasonal interception predicted by the STANDCARB model.

PET & Transpire Function

This function calculates the monthly total potential evapotranspiration (in cm) of the site using a modification of the Priestly-Taylor method (Bonan 1989, Jensen 1973). Total potential evapotranspiration for a month (*Mon*PETTotal) is assumed to be proportional to the estimated solar radiation (*Mon*SolRad), the monthly mean air temperature (*Mon*Temp24 in C), and number of days in a month (MonthDay).

*Mon*PETTotal=CT*(*Mon*Temp24+TX)**Mon*SolRad*MonthDay/*Mon*LatHeatVapor

The constants CT and TX are empirically derived and calculated after Jensen and Haise (1963) and Jensen (1973):

CT = 1/[38-(2*Elev/305) + 380/SatVapPresMax-SatVapPresMin)]

$$TX = 2.5+(0.14*(\text{SatVapPresMax}-\text{SatVapPresMin}))+\text{Elev}/550$$

where Elev is the elevation in meters, SatVapPresMin and SapVapPresMax are the saturation vapor pressures in mbars for the mean minimum (TempMeanMin) and mean maximum (TempMeanMax) daily temperatures for the warmest month of the year. The vapor saturation pressures are calculated from the appropriate air temperatures using Bosen's (1960) approximation. For example for the SatVapPresMin:

$$\begin{aligned}\text{SatVapPresMin}=33.8639*[&((0.00738*\text{TempMeanMin}+0.8072)^{8}\\ &- 0.000019*(1.8*\text{TempMeanMin} + 48) +0.001316)]\end{aligned}$$

*Mon*LatHeatVapor is the latent heat of vaporization (cal) for each month and is calculated as follows:

$$\mathit{Mon}\text{LatHeatVapor}= 597.-0.568*\mathit{Mon}\text{Temp24}$$

This means that each month can have its own value of latent heat of vaporization.

To estimate the potential amount of transpiration by plants (*Mon*PotenTrans), the total potential evapotranspiration (*Mon*PETTotal) is reduced by a constant fraction (as set in the Simul.drv file) to account for the evaporation portion of the water loss:

$$\mathit{Mon}\text{PotenTrans}=\mathit{Mon}\text{PETTotal}-\text{PETReduction}*\mathit{Mon}\text{PETTotal}$$

This yields a monthly potential transpiration loss assuming that leaf mass and soil water stores are at a maximum (Figures 15 & 16). The actual transpiration losses each month (*Mon*Transpiration) are controlled by the soil water stores and the foliage mass:

$$\mathit{Mon}\text{Transpiration}=\mathit{Mon}\text{PotenTrans}*\mathit{Mon}\text{MoistProdIndex}*(\text{Foliage}/\text{FoliageMax})$$

where *Mon*MoistProdIndex is calculated in the MoistProdIndex function and Foliage is the total foliage mass for all layers and FoliageMax is the maximum total foliage mass possible in a cell. This is calculated for each layer from the light compensation point (*Layer*LightCompPoint) and the light extinction coefficient (*Layer*LightExtCoeff) for each layer in

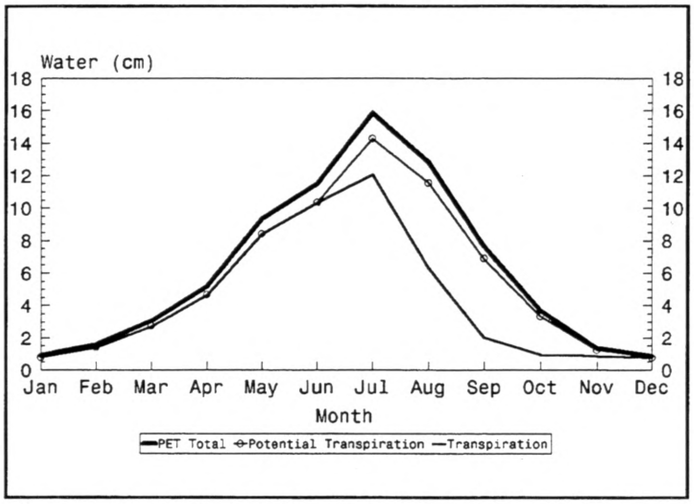

Figure 15. Relationship of Total PET, potential transpiration, and actual transpiration predicted by STANDCARB model.

a cell. The first step is to calculate the maximum light a layer (*Layer*MaxLightAbsorb) can absorb assuming that the overlying layers are also at their maximum:

*Layer*MaxLightAbsorb=*Layer*LightIn-(*Layer*LightCompPoint/100)

where *Layer*LightIn is the light not absorbed by the overlying layers and *Layer*LightCompPoint is the light compensation point of the layer as defined in the Growth.prm file. In cases where the *Layer*LightIn is less than *Layer*LightCompPoint (when the overlying layers reduce light below the light compensation point of the layer in question), *Layer*MaxLightAbsorb is set equal to zero.

The maximum mass of foliage a layer can have, adjusted for the amount of light it can absorb is:

*Layer*FoliageMax= -Ln [*Layer*LightRemoved/*Layer*LightExtCoeff

where *Layer*LightExtCoeff is the light extinction coefficient (defined in Growth.prm) and *Layer*LightRemoved is the amount of light removed by a layer:

*Layer*LightRemoved= (*Layer*LightIn-MaxLightAbsorbed)/*Layer*LightIn

The maximum foliage mass of all the plant layers is calculated as the sum of maximum foliage mass for all four layers in a cell:

FoliageMax=∑ (*Layer*FoliageMax).

In cases where a tree species has not been planted in a cell, the identity of the tree is determined as follows. In the single or multicell versions, the parameters associated with the herb and shrub layers are taken from the Growth.prm file to solve the potential maximum leaf mass. For tree layers this is not possible because a specific tree species must be identified for each layer. In the single cell version of the model, the identity of the upper and lower trees is taken from the Simul.drv file. In the case of the multicell version of the model, the species on the site that has the potential to have the maximum leaf mass is used until

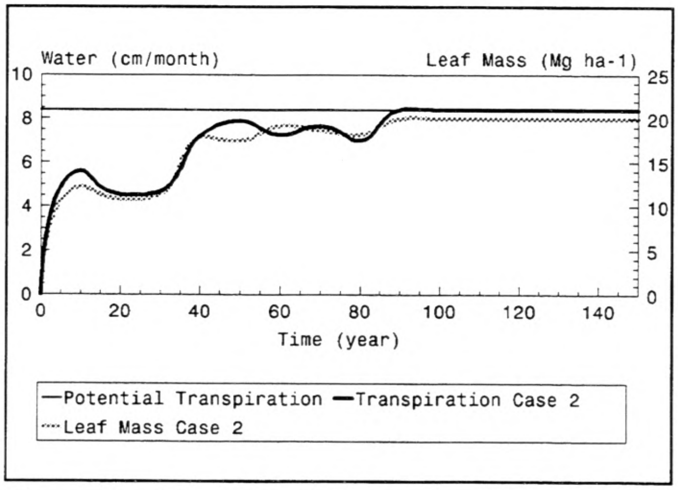

Figure 16. Example of change in peak transpiration predicted by STANDCARB over succession following rapid regeneration of Douglas-fir.

an actual species has been selected and planted.

WaterStore Function

This set of functions determines the monthly moisture content of six detrital pools followed in the DECOMPOSE objects and the mineral soil. For all pools, the moisture content is computed monthly and represents the balance of inputs through precipitation and outputs via evaporation and/or transpiration.

Mineral Soil Subfunction

This function computes the water stores in the mineral soil. For the mineral soil the input is whatever water has not been intercepted by the canopy, dead wood, and the dead foliage pools.

*Mon*SoilWaterIn=*Mon*DeadFoliageThroFall

where *Mon*SoilWaterIn is the amount of water added to the mineral soil layer in cm. The loss of water from the mineral soil will be controlled solely by the transpiration from plants. This assumes that there is always plant cover or forest floor cover. The overall balance of mineral soil water stores is therefore:

*Mon*DeltaSoilWat=*Mon*SoilWaterIn-*Mon*Transpiration

The water stored in mineral soil for each month would be:

*Mon*SoilWat= *Mon*SoilWatOld +*Mon*DeltaSoilWat.

where *Mon*SoilWatOld is the water store in the soil the previous month. In order to keep the water potential and other indices from becoming undefined, the minimum value that *Mon*SoilWat is allowed to have is 0.01.

In order to compute an overall water balance, runoff occurs when *Mon*SoilWat exceeds the SoilWaterMax (the maximum storage capacity of the soil based on its texture, rockiness, and depth as calculated by the SOILTEXTURE module).

*Mon*Runoff=*Mon*SoilWat-SoilWaterMax

When runoff occurs the *Mon*SoilWat is set to equal SoilWaterMax. If the monthly water store is less than or equal to the maximum then *Mon*Runoff is set to zero.

The annual Runoff is the sum of all the monthly values (TotalAnnualRunoff). While this variable is not directly used in carbon budgets, it is a useful variable for model calibration.

The moisture content of the soil is calculated on a volumetric basis relative to the maximum water storage of the particular site being examined:

*Mon*SoilMoist= 100**Mon*SoilWat/SoilWaterMax

where SoilWaterMax is the maximum amount of water (cm) a soil can hold as calculated in SOILTEXTURE.

Detrital Water Stores Subfunction

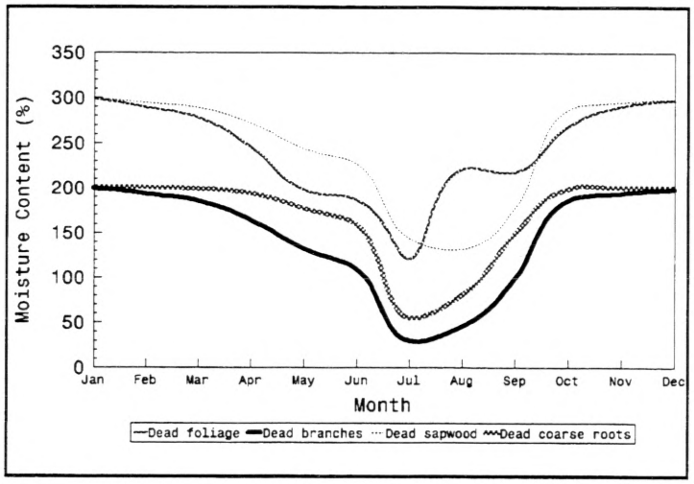

Figure 17. Example of seasonal changes in detritus moisture content predicted by STANDCARB.

This function calculates the balance of water stores for all six detritus pools (Figure 17). The input of water into each pool is equal to the amount intercepted:

*MonPool*WaterIn=*MonPool*Interception

In this version of the model these numbers are calculated for the DeadFoliage, DeadSapwood, DeadHeartwood, and DeadBranch pools. The loss of water each month from these pools is dependent upon the temperature and the amount of solar radiation received. The amount of solar radiation received by these layers each month is a function of the amount of light that passes through all the canopy layers (HerbLight as determined in the Light and Foliage function of the GROWTH module). Therefore:

*Mon*DetritusRadiationInput=*Mon*SolRad*HerbLightOut

where *Mon*SolRad is the total amount of solar radiation received by a site each month (see Radiate.drv file) and HerbLight is the fraction of light passing through the foliage of all the plant layers each month. The rate of drying is dependent upon the evaporative demand and the detrital pool being considered. The evaporative demand is calculated as:

*Mon*EvapDemand=*Mon*Temp24**Mon*DetritusRadiationInput

In the case that *Mon*Temp24 is negative, *Mon*EvapDemand is set to 0 so that detrital pools do not gain moisture directly from the atmosphere.

The rate that water is lost from a detrital pool is:

*MonPool*RateWaterLoss=*Mon*DetritusEvapDemand**Pool*DryingConstant

where *Pool*DryingConstant is found in the DcayParm.prm file. This parameter represents the rate of drying in month when the temperature is 1 C and the radiation input is 1 cal m^{-2} day^{-1}. The overall rate of change for each of the detrital layers is a function of the inputs versus loss through evaporation:

*Mon*Delta*Pool*Water=*MonPool*WaterIn
-*MonPool*RateWaterLoss**MonPool*WaterOld

The store of water in a layer for a given month would be:

*MonPool*Water=*MonPool*WaterOld+*Mon*Delta*Pool*Water

with the restriction that *MonPool*Water can not be less than 0.

To calculate the effect of water stores in these detrital layers on the Moisture Decay Index functions, the values of water depth have to be converted to moisture content based on mass. The mass of water per hectare in a cm of depth is 100 Mg. Therefore each 1 cm of water stored in a detrital layer is:

*MonPool*WaterMass=*MonPool*Water*100

where *Pool* is any of the four detrital layers we are considering (DeadSapwood, DeadHeartwood, DeadBranches, and DeadFoliage). The moisture content for these pools would therefore be:

*MonPool*Moist=100**MonPool*WaterMass/Pool.

where Pool is the mass of each detritus pool during the year being considered.

In this version of the model there are two layers that the moisture content is not modeled directly. For the dead fine root pool (DeadFineRoot), the moisture content is assumed to be the same as for the dead foliage pool. In the case of dead coarse roots (DeadCoarseRoot) the factors controlling the water balance of this pool are not known. Therefore we assumed that when dead branch moisture content is above 200% moisture content, dead branch and dead coarse root moisture contents are equal. When dead branch moisture content is below 200%, the moisture content of dead coarse roots is assumed to be greater than that of dead branches. This correction is not constant, but is zero at a dead branch moisture content of 0% and when it is 200 %. The maximum correction of 50% moisture content occurs when the dead branch moisture content is 100%.

If *Mon*DeadBranchMoist >200 then

$Mon\text{DeadCRootMoist}=Mon\text{DeadBranchMoist}$

If *Mon*DeadBranchMoist $<=$ 200 then

$Mon\text{DeadCRootMoist}=2*Mon\text{DeadBranchMoist} - 0.005*Mon\text{DeadBranchMoist}^2$

WaterPot Function

This function converts the volumetric moisture content of soils to a xylem water potential. This relationship is represented by a reciprocal function modified by an asymptote:

$Mon\text{WaterPot}=\text{CorrTerm}*\text{WaterPotAsym} + (\text{WaterPot1}*(\text{SoilWaterMax}/Mon\text{SoilWat}))$

where *Mon*WaterPot is the predawn xylem water potential in MPa for a given month, *Mon*SoilWat is the monthly water store in soil, and SoilWaterMax is the maximum water stores in cm (Figure 18). The latter variable is dependent upon the soil depth, rockiness, and texture and is calculated by SOILTEXTURE. The parameter WaterPotAsym simulates the behavior of coarse textured soils that can yield considerable water without changing their water potential. WaterPot1 is the fraction of the water stores when WaterPot is equal to 1 MPa. When this water potential is reached moisture becomes limiting to transpiration and production. The values of WaterPotAsym and WaterPot1 are defined in the Soil.prm file. Finally, the term, CorrTerm, is used to correct for the fact that water potential does not increase appreciably from 0 when the soil is near saturation. CorrTerm is set equal to 0 if the ratio of *Mon*SoilWat/SoilWaterMax is greater to or equal to 0.9. Otherwise CorrTerm is set to 1.

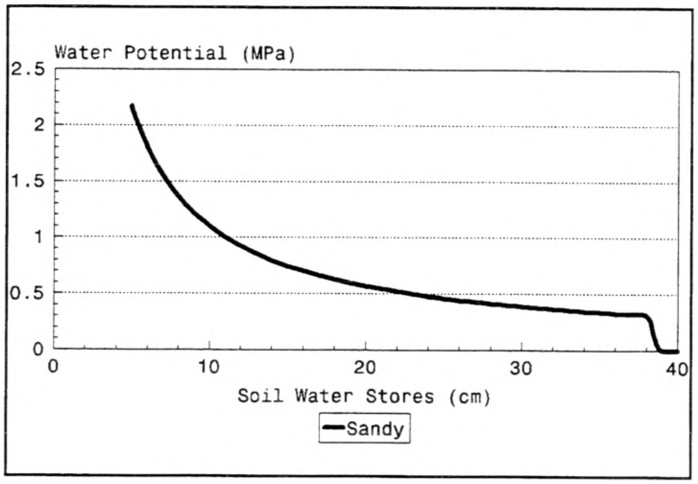

Figure 18. Relationship of soil water stores to water potential used by the model. Note water potential has been multiplied by -1 to convert to a positive scale.

MoistDecayIndex Function

This function determines the way the moisture content (*MonPool*Moist) of each pool influences the decomposition rate of the detrital layers for each month (Figure 19). For all layers we assume that moisture controls decomposition in two ways. The first is through matric potential which makes water unavailable for decomposers. For most detrital forms, decomposition ceases when moisture content reaches the fiber saturation point. The second effect is caused by poor oxygen diffusion when the moisture content is too high. For most detrital layers this is not a problem; however, coarse wood respiration is often limited by this factor. We model the matric potential and diffusion limitation portions separately. For all detritus pools except the stable soil pool, the percent moisture content used is based on mass of water divided by dry mass of the substrate. For the stable soil pool, the percent moisture content is based on volume of water divided by volume of soil.

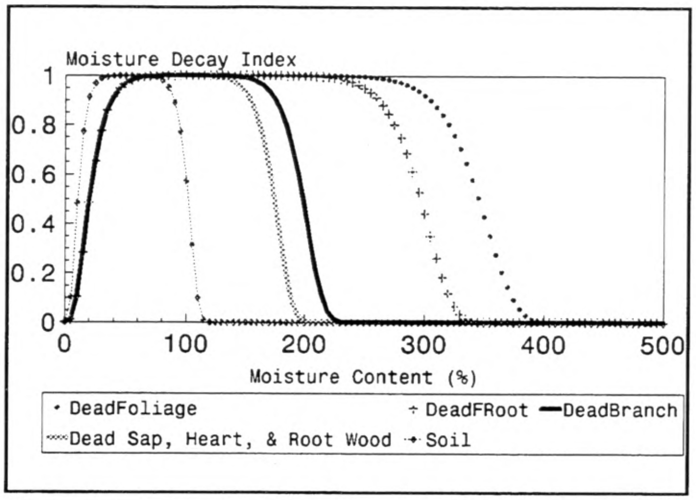

Figure 19. Response of decompostion to moisture content of various detrital pools.

The equation for the matric potential limitation (*Mon*MatricLimit) of each detrital pool or the stable soil pool for each month is:

$$MonPool\text{MatricLimit}=(1-\exp[-\text{IncreaseRate}*(MonPool\text{Moist}+\text{MatricLag})])^{\text{MatricShape}}$$

where MatricShape is a dimensionless number that determines when the Matric limit is reduced to the point that decay can begin to occur. The MatricLag parameter is used to offset the curve to the left or right. The IncreaseRate is the parameter determining the point at which the matric limitation ends. This parameter is determined from the minimum moisture content at which decay can occur:

$$\text{IncreaseRate}=3/\text{MoistMin}$$

The diffusion limitation (*Mon*DiffuseLimit) is designed to mimic the reduction in decomposition caused when the substrate becomes water saturated. This causes a reduction in the oxygen diffusion and this in turn reduces decomposition. This function remains at 1 until the maximum moisture content without diffusion limitations is reached. The function decreases to 0 when moisture content exceeds the maximum for decomposition to occur. This function is calculated for each detrital pool for each month:

$$MonPool\text{DiffuseLimit}=\exp[-(MonPool\text{Moist}/(\text{MoistMax}+\text{DiffuseLag})^{\text{DiffuseShape}}]$$

where MoistMax is the maximum moisture content without diffusion limitations, DiffuseShape is a dimensionless number that determines the range of moisture contents where diffusion is not limiting, and DiffuseLag is a parameter used to shift the point when moisture begins to limit diffusion. These parameters are stored in the DcayParm.prm file.

The combined effect of matric and diffusion limitations for each detritus pool or for the stable soil pool for each month is:

$$\mathit{MonPool}\text{MoistDecayIndex} = \mathit{MonPool}\text{MatricLimit} * \mathit{MonPool}\text{DiffuseLimit}$$

TempDecayIndex Function

This function determines the effect of temperature on the decomposition rate of the detrital pools. The response to temperature has two components (Figure 20). The first part is an increase in respiration rate with temperature following a Q10 type curve. For each detritus pool and each month the value of the following equation will be solved:

$$\mathit{MonPool}\text{TempIncrease} = (\mathit{Pool}\text{Q10}^{((\mathit{Mon}\text{Temp24-10})/10)})$$

where the respiration rate of the layer at 10 C is assumed to be 1.0, and *Pool*Q10 is the rate respiration increases with a 10 C increase in temperature (see the DcayParm.prm file) and *Mon*Temp24 is the temperature of a given month.

The second part of the temperature response simulates the effect of a lethal temperature limit that arrests decomposer activity. This equation is given by:

$$\mathit{MonPool}\text{TempLimit} = \text{Exp}[-(\mathit{Mon}\text{Temp24}/(\mathit{Pool}\text{TempOpt} + \mathit{Pool}\text{TempLag}))^{\mathit{Pool}\text{TempShape}}]$$

where *Pool*TempOpt is the optimum temperature for decomposition of a detritus pool and *Pool*TempLag and TempShape are parameters that determine the shape of the response curve and are determined from the DcayParm.prm file.

The combined effects of these effects for each detritus pool for each month is given by *MonPool*TempDecayIndex:

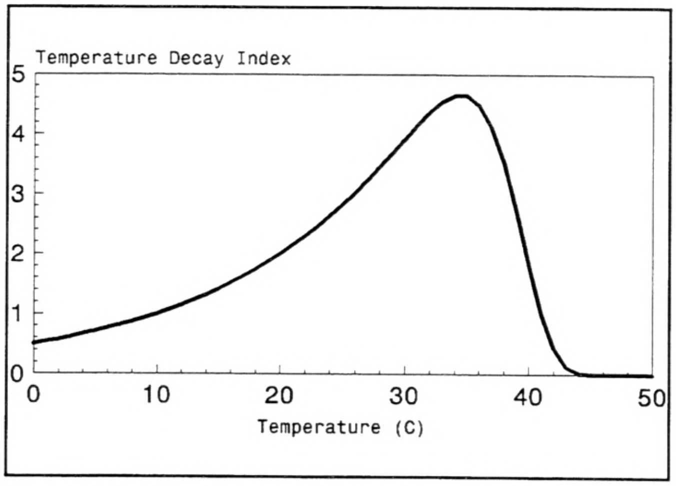

Figure 20. Response of decomposition to temperature.

$$\mathit{MonPool}\text{TempDecayIndex} = \mathit{MonPool}\text{TempIncrease} * \mathit{MonPool}\text{TempLimit}$$

AbioticDecayIndex Function

This function calculates the combined effects of temperature and moisture on the decomposition rate of each detrital pool and the stable soil pool for each month.

For each detritus pool or the stable soil pool the monthly abiotic decomposition index (_MonPool_AbioticIndex) is

_MonPool_AbioticIndex=_MonPool_MoistDecayIndex*_MonPool_TempDecayIndex

The mean annual AbioticIndex (_Pool_AnnualAbioticIndex) for each detritus pool or the stable soil pool is then used to control the decomposition rates in DECOMPOSE.

TempProdIndex Function

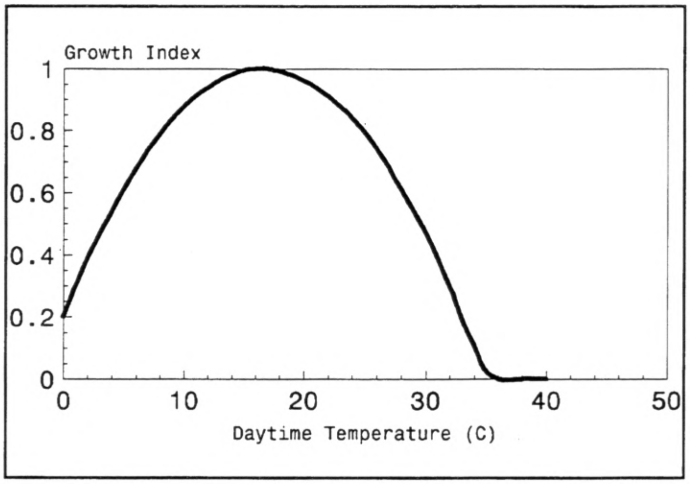

Figure 21. Response of Douglas-fir production to daytime air temperature.

This function determines the effect of temperature on net photosynthesis of each layer. The curve used to simulate this relationship is taken from Running and Coughlan (1988) and defines the mean daytime temperature (_Mon_TempDay see TempConvert function above) response according to a minimum and maximum temperature compensation point (_Layer_TempMin and _Layer_TempMax) for each layer as defined in the Growth.prm file. If the mean daytime temperature exceeds either the minimum or maximum temperature compensation points of a layer, then the temperature production index (_Layer_TempProd) for a layer is set to zero (Figure 21). If the day time temperature is within those limits then:

_MonLayer_TempProdIndex=(_Layer_TempMax-_Mon_TempDay)*(_Mon_TempDay-_Layer_TempMin)/(_Layer_TempMax-_Layer_TempOpt)*(_Layer_TempOpt-_Layer_TempMin)

where _MonLayer_TempProdIndex is a relative index of the response of each layer to a monthly daytime temperature (_Mon_TempDay).

The optimum temperature (_Layer_TempOpt) for a layer is defined as:

_Layer_TempOpt= (_Layer_TempMax-_Layer_TempMin)/2

MoistProdIndex Function

This function determines the effect of soil moisture on the production of live biomass. We assume that when soil water potential (WaterPot) is below -0.3 MPa, the production rate decreases exponentially (Emmingham and Waring 1977, Figure 22). The equation describing this is:

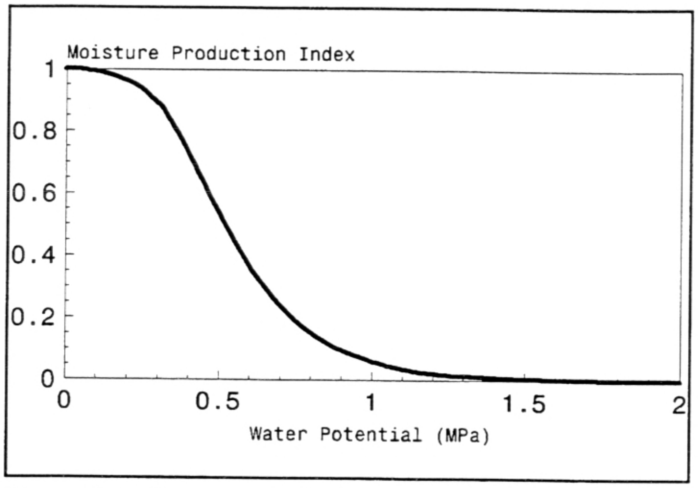

Figure 22. Response of plant growth to water potential. Note that water potential has been multiplied by -1 to transform it to a positive number.

$$\mathit{Mon}\mathrm{MoistProdIndex} = 1-(1-\exp[-5*\mathit{Mon}\mathrm{WaterPot}])^9$$

where *Mon*WatPot is the water potential in MPa as calculated by the WaterPot function.

ProdIndex Function

This function combines the monthly effects of moisture and temperature on the production rate of living biomass for each plant layer. In addition to indicating the response of production, it is also used to control the transpiration of the layers in the PET & Transpire functions. For each month the product of these two indices is computed:

$$\mathit{MonLayer}\mathrm{ProdIndex} = \mathit{MonLayer}\mathrm{TempProdIndex}*\mathit{Mon}\mathrm{MoistProdIndex}$$

The mean annual production index (AnnualLayerProdIndex) is then computed and used by GROWTH.

SOILTEXTURE

This module is used to estimate the maximum amount of water that can be stored in a soil profile for a site It is invoked once at the beginning of each simulation. This estimate is based on the soil texture class, the depth of the soil in cm, and the percentage of the soil with fragments greater than 2 mm in size that is specified in the Locat.drv file.

SoilTexture Function

This function determines the maximum amount of water storage in a soil based upon the soil texture, depth, and rockiness. The output of this function is sent to CLIMATE and used in the WaterPot and WaterStores functions.

This function first determines the fraction of the soil that can store water between field capacity and the wilting point (SoilWaterMaxPer) based on the soil texture class specified by the Locat.drv file. SoilWaterMaxPer is set for each soil texture class contained within the Soil.prm file.

The volume of rocks is used to decrease the overall water holding capacity. The fraction of the soil profile with fine soil (FineSoil) is calculated:

FineSoil=(100-Rocks)/100

where Rocks is the percentage of the soil with fragments greater than 2 mm diameter as specified in the Locat.drv file.

Finally, the depth of soil that can store water (SoilWaterMax) in cm is calculated from the soil texture, rock content and soil depth in cm:

SoilWaterMax=SoilWaterMaxPer*SoilDepth*FineSoil

where SoilWaterMaxPer is the percent of fine soil that can store water from field capacity to wilting point, SoilDepth is the depth of the soil in cm as defined in the Locat.drv file, and FineSoil is the fraction of the soil that is fragments less than 2 mm diameter.

PLANT

This function plants the vegetation layers and selects the species of tree to be planted in a cell. The first step is to determine if the herb, shrub, upper tree layer or the lower tree layer is present in a cell. If a layer is missing from the cell, then the PlantLife function is used to determine if the layer will be planted. If all these layers are present in a cell then PLANT moves to the next cell to determine which layers are present and need to be planted.

The files required by this function are Estab.prm and TreeReg.prm.

PlantLife Function

The purpose of this function is to determine if a life form is to be planted in a cell. If a life form is to be planted, then the life form specific growth and decomposition parameters are imported into the GROWTH and DECOMPOSE modules for that cell. In the case of a tree layer being selected the PlantTree function is invoked to select a tree species.

Life forms (i.e., herb, shrub, and trees) have unequal chances of being selected to be planted. The probability a layer will be planted is defined in the Estab.prm file for up to four cases or regeneration scenarios. For any simulation only one of these four cases can be selected. The layer of trees that is planted is dependent on the presence of the upper tree layer. The lower tree layer can only be planted when an upper tree layer is present. The upper tree layer can only be planted when the cell has no trees on it.

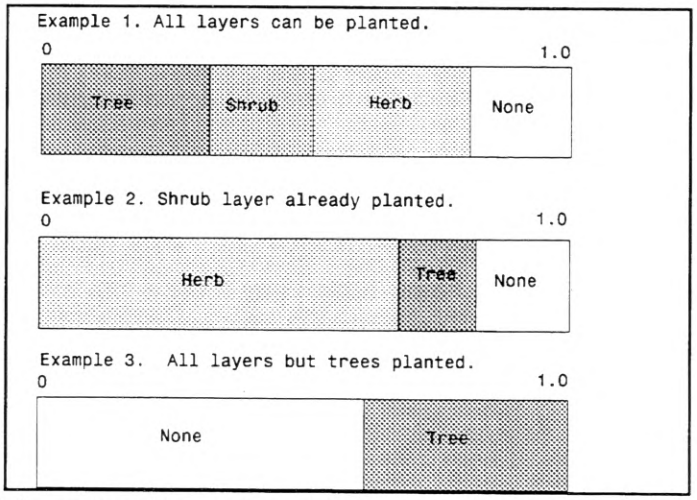

Figure 23. Examples of the cumulative probability function. Each case represents a possible situation.

Only one layer can be planted in a cell during each time step. To determine if a layer is to be planted, this function creates a cumulative probability function based on the probabilities of all the layers that have yet to be planted in a cell (Figure 23). The cumulative probability function can not exceed a value of 1.0 and is constructed by selecting one of the layers at random and assigning it a probability band from 0 to the probability specified in the Estab.prm file. The next layer is assigned a probability band from the high range of the first layer to the sum of the probabilities of the first and second layer. This process is continued until all the layers that have not been planted are considered. In many cases the summation of all the layer probabilities does not equal 1.0, and when this occurs the remaining probability band is assigned to "no layer" that time step. After the cumulative probabilities are calculated for each layer, a random number is selected between 0 and 1. Whichever probability band the number falls into determines which layer is planted that time step. If no layer is selected, then the function moves on to the next cell to determine which layers to plant on that cell.

If a layer is selected for planting, then a message is sent to GROWTH to make the mass of foliage for that layer a small positive number. Once the foliage mass is added the layer begins to grow and add biomass. Adjusting InitialFoliageMass (the value is specified in the GrowParm.prm file) determines the length of time lag required for the layer to begin growing at a significant rate. Setting this parameter low increases the lag time, whereas increasing it decreases the lag time.

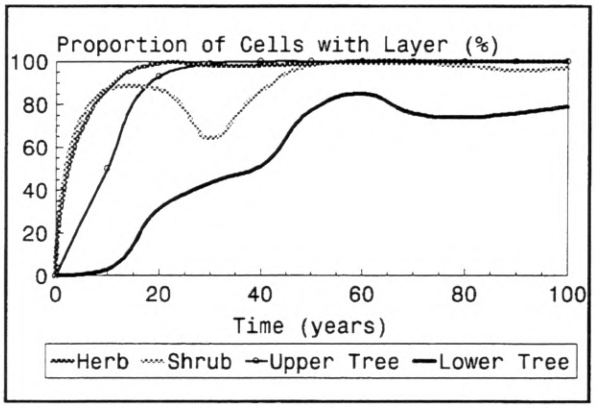

Figure 24. Example of layer colonzation for fast, artificial tree regeneration.

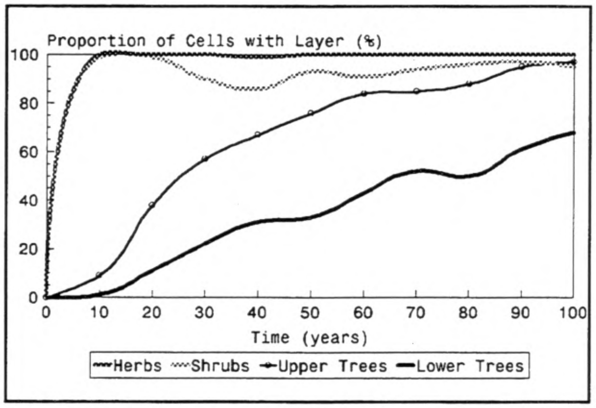

Figure 25. Example of layer colonization for slow, natural tree regeneration.

The probability of a layer establishing in a plot depends upon whether an upper tree layer exists. If there is no upper tree layer, then the probability of establishment that is used is EstOpen*Reg*, where *Reg* is regeneration scenario. There are four regeneration scenarios present in the Estab.prm file: 1) natural fast, 2) natural slow, 3) artificial fast, and 4) artificial slow (Figure 24 and 25). If there is an upper tree layer present, then the probability of establishment that is used is EstClosed*Reg*, where *Reg* is regeneration scenario.

The probabilities of establishment in the Estab.prm file are set so that herbs will tend to establish before shrubs and shrubs will establish before trees. The probability of trees establishing in the upper layer can be modified by the options selected in the Simul.drv file. The probability of a life form establishing beneath a tree canopy layer (EstClosed*Reg*) is always lower than the probability of establishing in the open (EstOpen*Reg*).

PlantTree Function

As specific species of the herb and shrub layers are not considered, it is not necessary to select which species herb or shrub should be planted. Trees, however, are treated on the species level. The PlantTree function selects which species can be planted. STANDCARB does not consider all the factors that control tree establishment. Rather the intent of the PlantTree function is to plant trees in proportion to their abundance in the various stages of succession.

The first step is to determine the response of a species to individual environmental factors. These are then combined to estimate the probability of a tree species establishing in a plot (Prob*Species*) from the local abundance (LocalAbund) and tolerances to the abiotic environment of the site (DDayMax, DDayMin, TreeSoilMax, TreeSoilMin, LightMax, LightMin). All these parameters are defined in the TreeReg.prm file. The limits to abiotic factors are set for a species, however, the local abundance (LocalAbund) varies with the specific location within the Pacific Northwest.

Temperature Limits. A species may not be planted if the thermal environment of the site exceeds the limits of a tree species. If the degree day values (DDays) of a site determined from the DegreeDays function of CLIMATE are equal to or below the degree day minimum (DDayMin), or equal to or exceed the degree day maximum (DDayMax) for a species, then its probability of establishment is set to zero (DDayLimit). If the DDays are within the limits then DDayLimit is set to one.

Soil Moisture Limits. A species of tree may also not be planted if the site is too dry or because it is too wet. If the yearly minimum soil water potential (MinMonWaterPot) calculated for a cell in the WaterPot function of CLIMATE is equal to or lower than the species minimum (TreeSoilMin), then the value of SoilLimit is set to zero. If the soil water potential exceeds the species maximum for more than 9 months, then SoilLimit is also set to zero. If the site soil water potential is within these limits, then SoilLimit is set to one.

Light Limits. A species of tree may not be able to establish within a cell if there is too much or too little light. In the former case, light *per se* may not be the limiting factor, excessive heating or drying may be the actual mechanism involved. These problems are highly correlated, however, to high light levels. In the case of the minimum light levels required for a species, this is related to the species shade tolerance and light compensation point.

The light value used to determine the probability a tree can establish depends upon if it is being planted as an upper tree or as a lower tree layer. For upper trees the value of light that is considered is the amount entering a cell (UpperTreeLightIn). This may fall below full sunlight if adjacent cells contain taller trees that shade the cell being considered (see NEIGHBOR module). For lower trees the value of light that is considered is the amount passing through the upper tree layer (LowerTreeLightIn) as determined by GROWTH. If the light value considered in either case is within the limits during the time step a species is being selected, then the value of *Layer*LightLimit is set to 1. If the light is equal to the maximum and minimum light limits or exceeds these values, the value of *Layer*LightLimit is set to zero.

The second step in determining the probability of a tree species establishing in a cell is to calculate a species ranking:

Rank*Species*=LocalAbund*DDayLimit*SoilLimit*LightLimit

These formulae do not allow a species to become established if the species is not present in the ecoregion or if the temperature, moisture, or light limits are exceeded.

The last step is to convert these ranks into proportions:

Prob*Species*=Rank*Species*/Rank*All*

where *Species* is the value for a given tree species and *All* is the sum of the values of all the species.

Once these probabilities are estimated, a cumulative probability is calculated in a manner similar to that used for determining which layers are to be planted. A tree species is selected at random and then the probability band it occupies is set from 0 to the probability determined above (Prob*Species1*). The next species has a probability band from the first species to the sum of probabilities for the two species (Prob*Species1*+ Prob*Species2*) and so on until all the species have been considered. A random number is then generated to determine which species will be planted in a plot. Whichever band the random number falls within determines which tree species is planted in that cell.

DIEOUT

This module determines when a upper canopy layer in a cell will die out completely. The rational is that as long as the canopy layer is comprised of more that one individual, the death of a tree will not cause the species to vacate the upper tree layer of a cell. Once the upper canopy is dominated by a single individual, however, there is some chance (ProbDieOut) that a species will disappear from the cell. The parameters used to define when trees die out (AgeMax and TimeClose) are contained within the Mort.prm file.

TimeThere Function

This function calculates the time a species has occupied the upper tree layer on a cell. Because not all the trees are planted in year 0, there is a difference between the simulation time and the time a tree species occupies a cell. To determine if an upper canopy layer has a chance of dying out, the time the species is on the site must be calculated:

TimeThere=Time-TimePlant

where time is the simulation Time in years, TimePlant is the simulation time that a species was planted in a layer, and TimeThere is the number of years a species has occupied the upper canopy layer of a cell.

ProbDieOut Function

This function calculates the chance an upper tree layer will die out and be replaced. The probability an upper tree layer will die out is a function of the time the species has occupied a cell. If the time since a species was planted in a cell (TimeThere) is less than TimeClose then :

ProbDieOut= 0

If the time since a species was planted in a cell (TimeThere) is greater than or equal to TimeClose defined in the Mort.prm file, then the probability is equal to:

ProbDieOut= ExtRate

where ExtRate is the annual probability that a species will die. This probability is calculated from the maximum age of the species (AgeMax) and the time required for a single tree to dominate a plot (TimeClose):

ExtRate=4.61/(AgeMax-TimeClose)

To determine if the upper canopy layer in a cell dies out, a random number is chosen. If this number is less than ProbDieOut then the species dies out of a cell.

Once the upper tree layer has died out of a cell, the lower tree layer, if present, becomes the upper tree layer (Figure 26). When a lower tree layer replaces an upper tree layer, the replacing layer is assumed to be 25 years of age. This partially compensates for the fact that the lower tree layer was planted prior to the death of the upper canopy layer. The time the replacing layer was planted is therefore estimated to be:

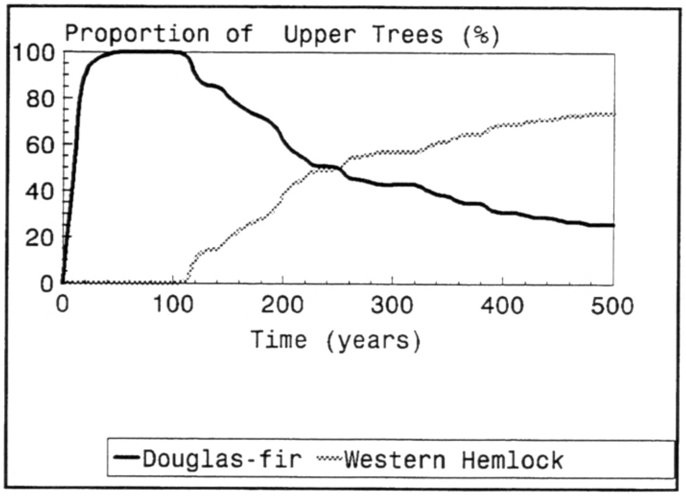

Figure 26. Example of replacement of Douglas-fir upper trees with western hemlock lower trees over succession.

TimePlant=Time-25

where Time is the simulation time when the upper tree layer dies and 25 is the assumed value of TimePlant when the lower tree layer replaces the upper tree layer.

GROWTH

The purpose of this module is to calculate the mass of six live pools of carbon: 1) foliage, 2) fine roots, 3) branches, 4) sapwood, 5) heartwood, and 6) coarse roots. To avoid confusion with the corresponding detrital pools, we have referred to these as parts. The functions in GROWTH are invoked each year for each cell.

This module is divided into eight functions which perform specific tasks. These include: 1) Light Absorption and Foliage, 2) Fine Root, 3) Allocation, 4) Respiration, 5) Heartwood Formation, 6) Mortality, 7) Prune, and 8) Live Stores. Each of these functions is invoked for each plant layer present in a cell.

The parts present depend on the plant layers present in a cell. Herbs are assumed to have leaves and fine roots only. Shrubs have leaves, fine roots, branches, sapwood, and coarse roots. Trees have leaves, fine roots, branches, sapwood, heartwood, and coarse roots. Boles are divided into two pools, sapwood and heartwood. This division is made because sapwood represents respiring tissue and heartwood represents non-respiring tissue. This approach also allows one to have the decay rate of dead wood a function of decay resistance of the heartwood of the trees species growing in a plot.

The files directly used by GROWTH are Growth.prm and GrowParm.prm.

Light Absorption and Foliage Function

This function determines the growth of the foliage layers and the amount of light absorbed by them. Light is expressed in relative terms as a percentage of full sunlight. We assume that taller layers have a competitive advantage over shorter stature layers; if taller layers are present they will absorb light before underlying layers (Figure 27). In this model smaller stature layers do not have the ability to exclude potentially taller layers. This behavior can, however, be simulated by reducing the colonization rate of the taller layers in the PLANT module (see Estab.prm file). In addition to being reduced by taller layers, when the model is run in the cell by cell interaction mode the light coming into a cell can be reduced by shading from surrounding cells (see NEIGHBOR).

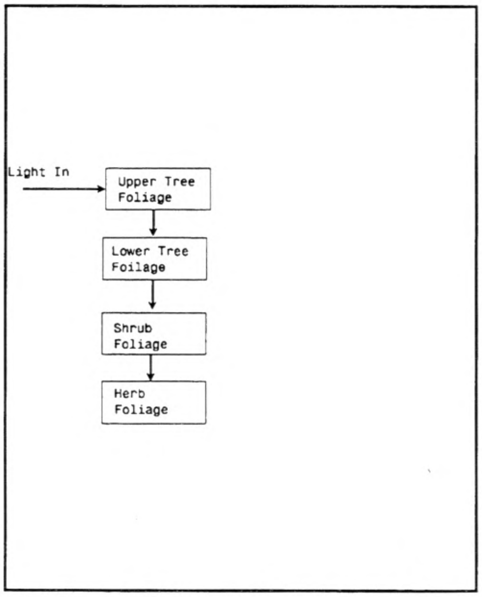

Figure 27. Interception of light by plant layers.

The foliage mass of a layer (*Layer*Foliage) will not begin to grow until a small mass of foliage is added to the foliage part of a layer by PLANT. This allows the mass of foliage to increase at a rate dependent upon the amount of light that has not been absorbed. If a layer has not been planted then the foliage production rate (*Layer*FoliageProdRate) for each layer is set to 0. Foliage production rate is an index that indicates the relative ability of foliage to produce more foliage. When this variable is 1, foliage increases at the maximum rate. When this variable is 0, foliage does not increase and when it is negative (i.e., an overlying layer establishes and absorbs light) the foliage mass decreases. Before a layer is planted the following condition is present:

The *Layer*FoliageProdRate=0

and

*Layer*Foliage=0

As soon as a layer is planted these variables are set:

FoliageProdEffic=1

and

Foliage=InitialFoliageMass

where InitialFoliageMass is the initial mass of foliage that is planted. InitialFoliageMass can be varied (see the GrowParm.prm file) to introduce a lag in the time required for a layer to grow significantly. By reducing this parameter one increases the lag in the growth of a layer.

Layers are able to increase their foliage mass until the light compensation point (LightCompPoint) for that layer or species of tree is reached.
As overlying layers can absorb light, the growth of underlying layers can be far below that expected for full sunlight. This approach also allows the foliage of the underlying layers to change in response to an overlying layer dying out or to an overlying layer establishing.

The first step to calculate the rate that foliage increases is to convert LightCompPoint from a percentage to a proportion.

*Layer*LightCompPoint=*Layer*LightCompPoint/100

The next step is to calculate the potential maximum light (*Layer*MaxLightAbsorb) that can be removed by each layer as a function of the amount of light that comes into the top of each layer and the light compensation point:

*Layer*MaxLightAbsorb=*Layer*LightIn-*Layer*LightCompPoint

where *Layer*LightIn is the relative fraction of full sunlight that reaches the top of a given layer. *Layer*MaxLightAbsorb is a dynamic variable and is calculated each time step because the amount of light removed by overlying layers or adjacent cells changes over time. To avoid possible cases where *Layer*MaxLightAbsorb could go negative (which happens if the light compensation point is larger than the light left over from an overlying layer) *Layer*MaxLightAbsorb is restricted to be greater than 0.

The amount of light (Light) remaining at base of the foliage of each layer is a function of the mass of foliage of that layer:

*Layer*Light=*Layer*LightIn*exp(-*Layer*LightExtCoeff**Layer*Foliage)

where *Layer*Light is the light passed to an underlying layer and *Layer*LightExtCoeff is the light extinction coefficient for a layer. For trees, the latter parameter is a function of the species present in a cell. The light coming into an underlying layer equals the light passing through the overlying layer. The layers are set up so that the upper tree layer absorbs light first, what is left over is "passed" along to the lower tree layer, and that "passes" along what is left over to the shrub layer, and finally the shrub layer passes along what ever is left over to the herb layer (Figure 16). If the foliage mass of a layer is zero then no light is absorbed. So a plot with only a herb layer would receive full sunlight (100%), but a herb layer under a upper and lower tree layer and a shrub layer would only receive whatever is not absorbed by those layers.

The next step is to calculate the light absorbed (*Layer*LightAbsorbed) by a layer:

*Layer*LightAbsorbed=*Layer*LightIn-*Layer*Light

The foliage production efficiency (*Layer*FoliageProdEffic) of a layer is assumed to decrease as the amount of light removed increases:

*Layer*FoliageProdEffic= 1-(*Layer*LightAbsorbed/*Layer*MaxLightAbsorb)^2

This function means that as the amount of light removed by a layer increases, its ability to increase its foliage mass decreases. When the light absorbed equals the maximum that can be absorbed then the foliage production efficiency equals 0. If the light absorbed exceeds the maximum then the leaves die, that is FoliageProdEffic is negative.

The absolute foliage production rate (*Layer*FoliageProdRate) of a layer is a function of the foliage production efficiency (*Layer*FoliageProdEffic) and the maximum absolute rate of foliage increase (*Layer*FoliageProdRateMax) in full sunlight (as defined in the Growth.prm file):

*Layer*FoliageProdRate=*Layer*FoliageProdEffic**Layer*FoliageProdRateMax

The rate that foliage mass of each layer increases (*Layer*FoliageAlloc) is:

*Layer*FoliageAlloc=*Layer*FoliageProdRate**Layer*Foliage

where *Layer*Foliage is the mass of foliage in a plant layer.

FineRoot Function

This function calculates the production of fine roots. Although the dynamics of fine roots are quite complicated, there is little information to model these dynamics. We therefore assume that there is a fixed ratio (*Layer*FineRootFoliageRatio) between the mass of fine roots and foliage. This ratio is life-form specific (herbs, shrubs and trees) and defined in the Growth.prm file. This assumption implies that the energy and nutrient gathering portions of plants are in balance. This ratio is assumed to be highest for herbs, intermediate for shrubs, and lowest for trees giving the highest allocation of biomass below ground for herbaceous plants and lowest for trees. The rate fine root mass for a layer can increase is therefore calculated from the foliage and this ratio:

*Layer*FineRootAlloc=*Layer*FineRootFoliageRatio**Layer*FoliageAlloc.

Allocation Function

This function allocates production by the foliage to the woody plant parts: sapwood, branches, and coarse roots. There are several assumptions used in the calculation of sapwood, branch and coarse root production. The first is that production of these parts is proportional to the mass of foliage of each layer. The second, is that the proportion of allocation to bole (i.e., sapwood and heartwood), branches, and coarse roots are fixed. The latter assumption is based on the idea that these are structural elements that need to be balanced together in order to function properly. Although the allocation of production to these wood parts is fixed, this does not mean that the portions of woody parts is constant. This is because the pruning of branches and coarse roots, as calculated by MORTALITY, is a function of the amount of light absorbed by a cell. Therefore, cells with less light absorbed (and therefore less competition) will have more branches and coarse roots than those where the maximum amount of light has been absorbed.

The allocation to woody plant parts can be determined by two methods. The first is based on calibration to yield curves. This will set the growth rate so that the wood volume matches that of a specified level of productivity or site index for a selected species. If this option is specified in the Simul.drv file, then the variable *Layer*GrowthRate is set to the value referred to in the SiteIndx.prm file. *Layer*GrowthRate can be thought of as the ability of foliage to form woody tissues.

The second method used to determine the allocation to woody parts is to base the growth rate on climatic indices calculated in CLIMATE. If this option is specified in Simul.drv, then:

*Layer*GrowthRate=*Layer*AnnualProdIndex**Layer*GrowthEffic

where *Layer*AnnualProdIndex is the effect of temperature and moisture on growth for a layer and *Layer*GrowthEffic is the growth efficiency for a layer as specified in the GrowParm.prm file.

Regardless of the method used, the mass of production allocated from foliage to sapwood is:

*Layer*SapWoodAlloc=*Layer*GrowthRate**Layer*Foliage

where *Layer*SapWoodAlloc is the mass of sapwood produced by a layer, *Layer*Foliage is the mass of foliage of a layer, and *Layer*GrowthRate is the ratio of wood mass produced to foliage mass. This relationship makes sapwood production reach a maximum when foliage mass is at a maximum. If foliage mass is reduced by thinning or reduced by shading then the rate of sapwood production will also be reduced.

The amount of production allocated to branches from foliage for trees and shrubs (*Layer*BranchAlloc) is equal to a fixed proportion of the rate of sapwood production for that layer. The parameter *Layer*BranchBoleRatio defines the ratio of branch to sapwood production. In the model this parameter is set to give the proportions of a tree greater than 50 cm diameter at breast height as solved by biomass equations (Means et al. 1994). The mass of branches produced for a layer is therefore:

*Layer*BranchAlloc=*Layer*BranchBoleRatio**Layer*SapWoodAlloc

The mass of production allocated to coarse roots from foliage (*Layer*CoarseRootAlloc) for the tree and shrub layers is calculated in a manner similar to branches:

*Layer*CoarseRootAlloc=*Layer*CoarseRootBoleRatio**Layer*SapWoodAlloc where *Layer*CoarseRootBoleRatio is the ratio of coarse root to sapwood production of a layer as defined in the Growth.prm file.

Respiration Function

The purpose of this function is to estimate the respiration of the plant parts for each layer. Foliage, fine roots, branches, sapwood, and coarse roots all are capable of respiring. Heartwood is not capable of respiring. Due to the manner in which changes in foliage and fine mass are calculated, the respiration rates calculated here are used to give an estimate of the total gross production. The respiration rates for branches, sapwood, and coarse roots are used to calculate the total gross production and to calculate the net production of those parts in the Live Stores function (see below). To give an estimate of gross production, the respiration losses of all plant parts except heartwood are estimated from their mass:

*LayerPart*Resp=*LayerPart*RespRate**Layer*Part.

where *LayerPart*Resp is the mass of production that respired by a plant part, *LayerPart*RespRate is the rate as a proportion of each part, and *Layer*Part is the mass of each part for a layer the previous time step. *LayerPart*RespRate is calculated as a function of the species and the mean annual ambient temperature (MeanAnnualTemp) for the site (see the MeanAnnualTemp function in CLIMATE). For all plant parts the proportion of mass respired each year is:

*LayerPart*RespRate=*Layer*Resp*Part*10 *Q10*Part*^((MeanAnnualTemp-10)/10)

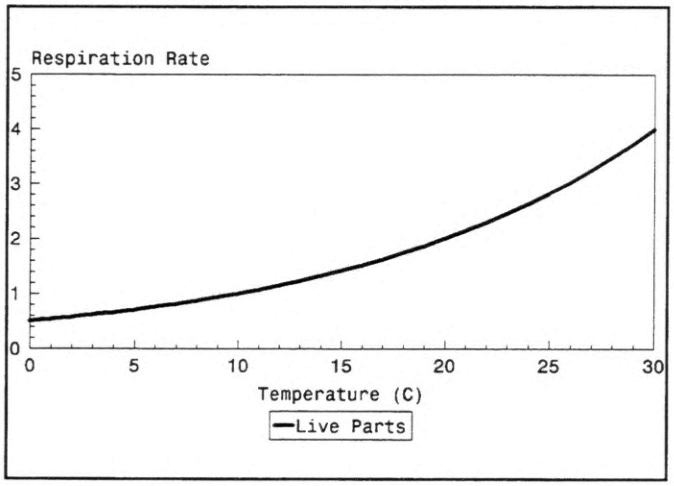

Figure 28. Response of living part respiration to temperature.

where *Layer*Resp*Part*10 is the respiration rate of the plant part at 10 C, Q10*Part* is the rate respiration increases with a 10 C increase in temperature and MeanAnnualTemp is the mean annual temperature (Figure 28).

For foliage, fine roots, branches, and coarse roots the fraction that is alive is constant among species and layers. In the case of sapwood, adjustments are made to *Layer*RespSapwood10 to reflect the fact that tree species have differing proportions of the sapwood that is alive. The respiration rate for sapwood contained in the

Growparm.prm file is based on a living sapwood fraction of 5%. The rates used are based on respiration of lodgepole pine and Engelmann spruce (Ryan 1990). This base rate is adjusted by:

*Layer*RespSapwood10=*Layer*RespSapwood10*(*Layer*SapLive/5)

where *Layer*SapLive is the percentage of the sapwood of a layer that is alive. This parameter is stored in the Growth.prm file and is tree species specific based on the proportion of ray cells in sapwood (Panshin and de Zeelu 1970).

Heartwood Formation Function

This function calculates the rate that heartwood is formed from sapwood for the tree layers. The mass transferred from sapwood to heartwood (*Layer*HeartWoodAlloc) for each tree layer is determined by the rate of heartwood formation (*Layer*RateHeartWoodForm) and the mass of sapwood (*Layer*SapWood) for the previous time step:

*Layer*HeartWoodAlloc=*Layer*RateHeartWoodForm**Layer*SapWood

*Layer*RateHeartWoodForm is parameterized so that the proportion of boles in sapwood matches the values in mature trees of the various tree species (Figure 29).

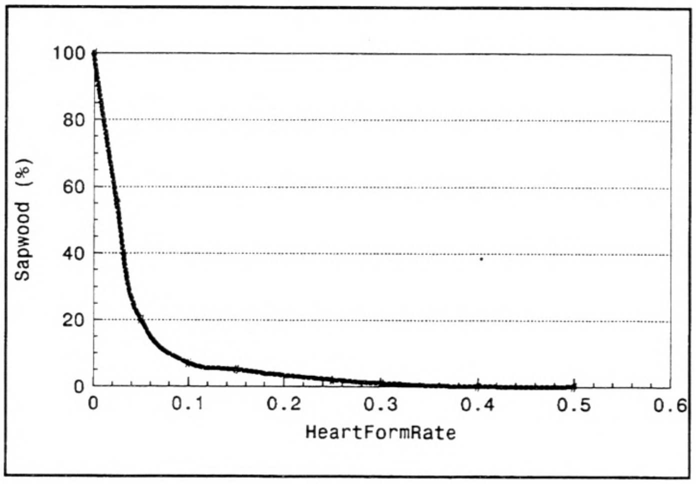

Figure 29. Relationship between rate of heartwood formation and proportion of bole in sapwood.

Mortality Function

This function calculates the mass of all plant parts lost by normal mortality processes. Even without harvest or wildfire some of the trees are subject to mortality caused by competition (self thinning), wind, insects, and pathogens. It is assumed that when trees and shrubs are subject to natural mortality, all the plant parts for that plant are added to detrital pools. The equation describing these losses is:

*LayerPart*Mort=*Layer*MortalityRate**LayerPart*

*Layer*MortalityRate is the proportion of trees or shrubs dying and is calculated in MORTALITY and *LayerPart* is the mass of a layer from the previous time step. This parameter does not remain constant, but increases as the amount of light absorbed increases so that when the maximum amount of light is absorbed, the maximum mortality rate is reached. This mimics the increased competition among individuals as the canopy closes.

Prune Function

This function calculates the mass of foliage, fine roots, branches, and coarse roots that are lost to litterfall, fine root turnover, or pruning. The mass of these plant parts for each layer lost to these processes is:

*LayerPart*Prune=*LayerPart*TurnoverRate*Layer*Part*

where Layer*Part*Prune is the mass of plant parts of a layer lost from normal foliage fall and pruning, *LayerPart* is the mass from the previous time step of the live part being considered, and *LayerPart*TurnoverRate is the fraction of the part for a layer that is pruned or replaced in a given year. *LayerPart*TurnoverRate has different names depending upon the plant part considered. FoliageTurnoverRate, FRootTurnoverRate, BranchPruneRate, and CRootPruneRate are used for foliage, fine roots, branches and coarse roots, respectively. All these variables are calculated in MORTALITY.

Live Stores Function

This function calculates the mass of the plant parts after normal growth and mortality. The change in mass for each plant part caused by harvest and fire are calculated by HARVEST and BURNKILL, respectively. The balance of non-woody plant parts (i.e., foliage and fine roots) are calculated as follows:

*Layer*Part = *Layer*PartOld + *LayerPart*Alloc

Where *Layer*PartOld is the mass of the part from the previous year, and *LayerPart*Alloc is the mass of the plant part produced (for foliage this is *Layer*FoliageAlloc and for fine roots this is *Layer*FineRootAlloc).

For branches and coarse roots the mass in any year is:

*Layer*Part = *Layer*PartOld + *LayerPart*Alloc -*LayerPart*Resp- *LayerPart*Prune
-*LayerPart*Mort

Where *Layer*PartOld is the mass of the part from the previous year, *LayerPart*Alloc is the mass of the plant part produced (for branches this is *Layer*BranchAlloc and for coarse roots this is *Layer*CoarseRootAlloc), *Layer*Part is the mass of plant part for that year, *LayerPart*Resp is the mass respired, *LayerPart*Prune is the mass pruned, and *LayerPart*Mort is the mass dying with boles (i.e., Sapwood and Heartwood) because of normal mortality. The latter term also includes death of shrub layers.

The mass of sapwood for a layer is calculated as:

*Layer*Part = *Layer*PartOld + *LayerPart*Alloc -*LayerPart*Resp
-*Layer*SapWoodHeartWoodAlloc-*LayerPart*Mort

where all the variables are the same as for branches and coarse roots except that *Layer*SapWoodHeartWoodAlloc is the mass of sapwood allocated to heartwood.

The mass of heartwood for a layer is calculated as:

*Layer*Part = *Layer*PartOld + *LayerPart*Alloc -*LayerPart*Mort

where all the variables are defined as for the other plant parts. In the case of heartwood *LayerPart*Alloc is *Layer*SapWoodHeartWoodAlloc, the mass of sapwood allocated to heartwood formation.

In addition to these plant parts the mass in boles for the upper or lower tree layers is calculated as

*Layer*Bole=*Layer*Sapwood+*Layer*Heartwood.

The total live mass is the sum of all the live parts:

*Layer*TotalLive= $\sum$ (*Layer*Part)

where LayerPart is the mass of the part for each layer. In addition to these totals, the total mass of each part is also summed across all the layers.

Volume Function

This function converts the mass of boles from a cell for a given year to wood volume. The volume of bole wood is estimated from the bole mass (Bole) and the fraction of boles in wood (WoodPer) and the wood density (WoodDen) for the given species in a cell and layer. The parameters WoodPer and WoodDen are stored in the Growth.prm file.

The total mass of boles for a tree layer in a cell is:

Wood=Bole*WoodPer/100

where WoodPer is the percentage of the bole mass that is wood as opposed to bark (Wilson et al.1987). The volume of wood (Volume) is calculated by dividing the wood mass (Wood) by the wood density (WoodDen):

Volume=Wood/WoodDen

The values of wood density for each species are based on Marglin and Wahlgren (1972) and Wilson et al. (1987). Note the units are cubic meters per ha.

MORTALITY

The purpose of the MORTALITY module is to calculate the mortality, pruning, and turnover rates of plant parts (foliage, fine roots, branches, sapwood, heartwood, and coarse roots) associated with normal growth processes of all plant layers (Figure 30). The rate that is calculated depends on the layer and the plant part being considered. These variables are used by GROWTH and DECOMPOSE to adjust the live mass of parts or to calculate inputs to detritus pools. Detritus inputs associated with either harvest or fire are calculated by HARVEST or BURNKILL, respectively.

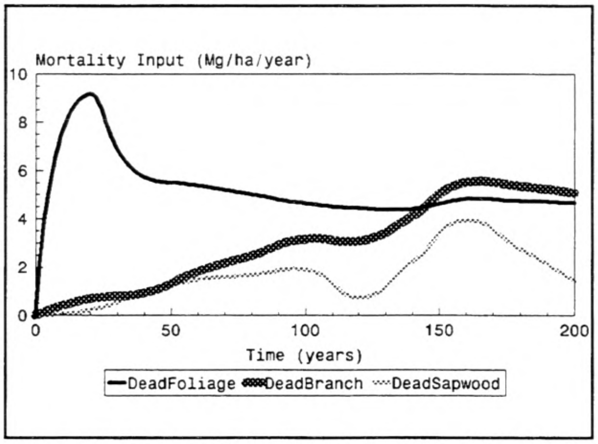

Figure 30. Example of trends in mortality inputs over succession. Inputs of all detrital pools are caculated; only 3 are shown.

During the course of normal growth, the mortality of sapwood and heartwood occurs when a tree dies. In contrast, the mortality of foliage, fine roots, branches, and coarse roots occurs when a tree dies or when parts are pruned. That is, when the sapwood and heartwood of a tree dies, we assume that all the associated plant parts will also die. There is, however, some mortality of these non-bole plant parts even when a tree does not die caused by normal pruning and replacement.

The parameters required by this function are stored in the Mort.prm file.

PlantMort Function

This function determines the mortality rate of plant layers that occurs from competetion with other layers and individuals within a layer. The rate of mortality is dependent upon whether the single cell or multicell version of the model is being used, the plant layer involved, the amount of foliage present in a layer, and in the case of upper trees the time it has occupied a cell.

In the single cell version of the model, upper tree mortality occurs in the cell every year of the simulation. This is because the upper tree layer represents a population of trees and never becomes a single tree. For the lower tree and shrub layers mortality also occurs every year. In the case of herbs, mortality only occurs when the foliage mass drops below a threshold mass very close to zero, and at that point all live parts are transferred to the appropriate detritus pools. Lower trees and shrubs can also have all their mass transferred to the detritus pools if their foliage mass drops below a threshold level.

In the multicell version herb, shrub and lower tree mortality is calcualted as for the single cell version of the model. However, upper tree mortality in the multicell version is calculated in one of two ways depending on the time an upper tree has occupied a cell. For the lower trees and shrubs, mortality occurs each year of the simulation, and for herbs only when the foliage mass drops below a threshold value. As with the single cell version, lower trees and shrubs can also have complete mortality when their foliage mass drops below a minimum threshold. In the case of upper trees, however, the layer may either represent a population or a single individual depending on the amount of time it has occupied the upper tree layer. For a given cell, upper tree mortality occurs each year that the time a species has occupied the upper canopy layer (TimeThere) is less than the age required for a single tree to occupy a cell (TimeClose). If the time a species occupies a cell is greater than TimeClose, then upper tree mortality is set to 0 until the DIEOUT function determines the species has died-out of a cell.

In the single cell version of the model the mortality of all the layers except herbs is calculated as:

*Layer*MortRate=MortMax*(LightAbsorbed/MaxLightAbsorb)

where *Layer*MortRate is the rate shrubs, upper or lower trees die, LightAbsorbed is the amount of light absorbed by the layer, and MaxLightAbsorb is the maximum amount of light that can be absorbed by the layer. The later two variables are calculated by GROWTH. This function increases mortality as a positive function of the total amount of light removed, mimicking the phase of self thinning during the middle stages of stand development.

Herb mortality in the single cell version of the model is set equal to zero if the foliage mass of this layer exceeds the minimum threshold:

HerbMortRate=0

For the lower tree, shrub, and herb layers in the single cell version of the model, it is possible for a layer to die completely out if there is not enough light to support foliage of that layer. If the foliage mass of these layers drops below a minimum threshold (set very close to zero), then the mortality rate of these layers is set to:

HerbMortRate=1.0

ShrubmortRate=1.0

LowerTreeMortRate=1.0

In the multicell version of the model the mortality of the herb, shrub, and lower tree layers is calculated exactly the same as in the single cell version of the model. For upper trees that have occupied cells fewer years than TimeClose, the mortality rate is also calculated as in the case for the single cell version. However, if the time an upper tree species has occupied an upper canopy layer (TimeThere) is equal or greater than the age required for a single tree to occupy a cell (TimeClose), then the upper tree mortality rate can be either 0 or 1. If the upper tree layer does not die out (see DIEOUT), then the upper tree mortality rate is:

UpperTreeMortRate=0.

where UpperTreeMortRate is the mortality rate of the upper tree layer. If the DIEOUT object determines that the upper tree layer in a cell shall be replaced, mortality of the entire upper tree layer in a cell occurs:

UpperTreeMortRate=1.0

BranchPrune Function

This function determines the rate that branches of upper and lower canopy trees and shrubs are lost via pruning. The rate branches are pruned (BranchPruneRate) is positive function of the total amount of light removed and the maximum rate of pruning for an intact stand (BranchPruneMax):

BranchPruneRate=BranchPruneMax*(LightAbsorbed/MaxLightAbsorb)

where LightAbsorbed is the amount of light that is absorbed by a tree or shrub layer and MaxLightAbsorb is the maximum light available for the layer to absorb as calculated in GROWTH.

Unlike the TreeMort function, branch pruning occurs for shrubs, lower, and upper canopy trees regardless of the time layers have been in a cell and whether the single or multicell versions are run. In the case of the multicell version, however, if DIEOUT determines if the upper tree layer dies out from a cell, then BranchPruneRate for the upper canopy layer is set equal to zero:

UpperTreeBranchPruneRate=0

This method is used because when upper tree layers die out, the transfer of branches to dead branches is accounted for by the TreeMort function (see the GROWTH object description).

CRootPrune Function

The rate coarse roots of upper and lower trees and shrubs are pruned is calculated by this function. The rate coarse roots are pruned (CRootPruneRate) is positive function of the total amount of light removed and the maximum rate of pruning for an intact stand (CrootPruneMax):

CRootPruneRate=CRootPruneMax*(LightAbsorbed/MaxLightAbsorb)

where LightAbsorbed is the amount of light that is absorbed by a layer and MaxLightAbsorb is the maximum light available for the layer to absorb as calculated in GROWTH.

As with branch pruning, coarse root pruning occurs for shrubs, lower, and upper canopy trees regardless of the time trees have been on a cell and whether the single or multicell versions are run. In the case of the multicell version, however, if the DIEOUT object determines the upper tree layer dies out from a cell, then CRootPruneRate for the upper canopy layer is set equal to zero:

UpperTreeCRootPruneRate=0

This method is used because the transfer of coarse roots to dead coarse roots associated with trees dying out of a cell is accounted for by the TreeMort function (see the GROWTH module description).

Foliage Function

This function determines the rate of foliage turnover used in DECOMPOSE. For all the plant layers the rate foliage is added to the DeadFoliage pool is defined by LeafTurnoverRate as stored in the Mort.prm file. An exception is when the upper tree layer dies out from a cell, then:

UpperTreeLeafTurnoverRate=0

This method is used because the transfer of foliage to dead foliage associated with an upper tree dying out of a cell is accounted for by the TreeMort function.

FineRoot Function

This function determines the rate of fine root turnover used by DECOMPOSE. For all the plant layers the rate fine roots are lost is defined by FineRootTurnoverRate as stored in the Mort.prm file. An exception is the case when the upper tree layer in a cell is selected to die out by the DIEOUT object, then:

UpperTreeFineRootTurnoverRate=0

This method is used because the transfer of fine roots to dead fine roots associated with an upper tree dying out of a cell is accounted for by the TreeMort function.

DECOMPOSE

This module is used to simulate the input, decomposition, and storage of carbon in detritus. Six pools of detrital carbon are considered: 1) the **dead foliage** derived from foliage, 2) **dead fine roots** which can be either in the organic or mineral soil 3) **dead branches** (fine woody debris) derived from branches, 4) **dead sapwood** (one form of coarse woody debris), 5) **dead heartwood** (another form of coarse woody debris), and 6) **dead coarse roots**. All detrital pools are named after the corresponding live plant parts with the prefix Dead added. In addition to these detrital pools, the model simulates the dynamics of a **stable soil** pool that potentially receives inputs from all six detrital pools.

All of the plant layers can input detritus into DECOMPOSE, however, some life forms do not have certain woody parts and therefore do not add these to the woody detrital pools. Herbs are assumed to contribute to the dead foliage and dead fine roots only. Shrubs contribute to the dead foliage, dead fine roots, dead branches, dead sapwood, and dead coarse roots. Finally, trees contribute to all the detrital pools including dead foliage, dead fine roots, dead branches, dead sapwood, dead heartwood, and dead coarse roots.

The inputs of material to the detrital pools comes from three potential sources: 1) normal litterfall and mortality, 2) thinning and harvesting, and 3) fire killed plants. The first input is calculated by MORTALITY, the third by HARVEST, and the last by BURNKILL. Although pools receive inputs from the four plant layers, the input mass is combined and the substrate quality are averaged so that only one detrital pool exists for each cell. The input of material into the stable soil pool is determined by the mass of the detrital pools as well as the transfer rates stored in the DcayParm.prm file.

The rate that each detrital pool decomposes is determined by the species (as parameterized by the Decomp.prm file), and the climate as calculated by CLIMATE. Decomposition rates of the stable soil pool are determined by the rates stored in the DecayParm.prm file as modified by climatic factors calculated by CLIMATE.

The stores of detritus calculated in DECOMPOSE are used by CLIMATE to calculate the interception of water by the dead foliage and woody detrital pools. The dead fine root, dead coarse root, and stable soil pools are assumed to not intercept water for water balance purposes.

The files directly used by DECOMPOSE are Decomp.prm and DcayParm.prm.

Detritus Input Function

This function is used to calculate the total input into each of the six detrital pools. The inputs of material to the detrital pools comes from three potential sources: 1) normal litterfall and mortality associated with self-thinning or the dying out of the upper tree layer, 2) thinning and harvesting, and 3) fire killed plants. For any given year, the input can come from several of these sources. Each year the inputs from normal litterfall and mortality and upper tree die out are calculated first, and then additional inputs from harvesting or burning are added. The inputs from harvest and fire are calculated in separate time steps that represent a fraction of a year. This method is used to avoid possible conflicts in calculating the mass of pools.

Inputs to each of the detrital pools are calculated as follows where *Pool* represents a specific detrital pool, *Layer* represents a plant layer, and *Part* represents a plant part:

For the parts foliage, fine roots, branches, and coarse roots in cells not harvested or burned, the input is :

$$\mathit{LayerPool}\text{Input}=\mathit{Pool}\text{TurnoverRate}*\mathit{Part} + \mathit{Layer}\text{MortRate}*\mathit{Part}$$

where *LayerPool*Input is the input mass from normal leaf fall and pruning for a particular layer and part, *Part* is the mass of the live part being considered, *Pool*TurnoverRate is the fraction of the part for a layer that is pruned or replaced in a given year and *Layer*MortRate is the mortality rate of a specific layer. *Pool*TurnoverRate has different names depending upon the plant part considered; FoliageTurnoverRate, FRootTurnoverRate, BranchPruneRate, and CRootPruneRate are used for foliage, fine roots, branches and coarse roots, respectively. All these variables are calculated by MORTALITY. *Layer*MortRate it is also calculated in MORTALITY and accounts for the input of non-bole parts associated with the mortality of entire plants in the layers. This includes the death of upper canopy trees that are selected to be replaced by the DIEOUT object, individuals that are self-thinned or the complete mortality of layers caused by insufficient light to support their foliage.

For the parts sapwood and heartwood in cells not harvested or burned the input is:

$$\mathit{LayerPool}\text{Input}=\text{MortRate}*\mathit{Part}$$

where *LayerPool*Input in this case is the input mass from sapwood and heartwood of dying trees, *Part* is either sapwood or heartwood mass, and MortRate is the mortality rate of trees calculated in MORTALITY. As for the non-bole parts, MortRate includes the death of upper canopy trees that are selected to be replaced by the DIEOUT object.

Plant parts from layers can also be added to detrital pools when trees are harvested during thinning or clear-cutting. These inputs are calculated after normal mortality inputs are calculated in a separate time step that represents a fraction of a year (e.g., 12.1). If the trees in a cell are thinned or harvested then the inputs from foliage, fine roots, branches, sapwood, heartwood, and coarse roots are:

$$\mathit{LayerPool}\text{Input}=\mathit{Pool}\text{Harv}$$

where *Pool*Harv is the amount of material generated from a layer as input to a detrital pool by harvest activities from HARVEST.

Finally, plant parts from layers can be added to detrital pools when plants are killed by site preparation or wildfires. These inputs are calculated after normal mortality inputs and harvest inputs are calculated in a separate time step that represents a fraction of a year (e.g., 12.2). If plants in a cell are killed by fire, then the inputs from foliage, fine roots, branches, sapwood, heartwood, and coarse roots are:

$$\mathit{LayerPool}\text{Input}=\text{BurnInput}\mathit{Pool}$$

where BurnInput*Pool* is the amount of plant parts killed by fire but not consumed as calculated by BURNKILL.

The total input to a pool (*Pool*Input) at any time step is the sum of all the inputs from the layers in a cell.

$$\mathit{Pool}\text{Input}= \sum (\mathit{LayerPool}\text{Input})$$

Detritus Substrate Effect Function

This function calculates the effect of the substrate quality of the various inputs on the overall decomposition rate of a detrital pool. This function is invoked each time inputs are added to a cell. Thus is possible to invoke this function three times in one year if normal growth, harvest, and fire occurs in a year. The decomposition rate of leafy litter used to parameterize STANDCARB is based on the relationship of the lignin:nitrogen ratio of a species versus the annual decomposition rate (Harmon et al. 1990a). The decomposition of woody detritus is based on the comparative decay resistance of species (Forest Products

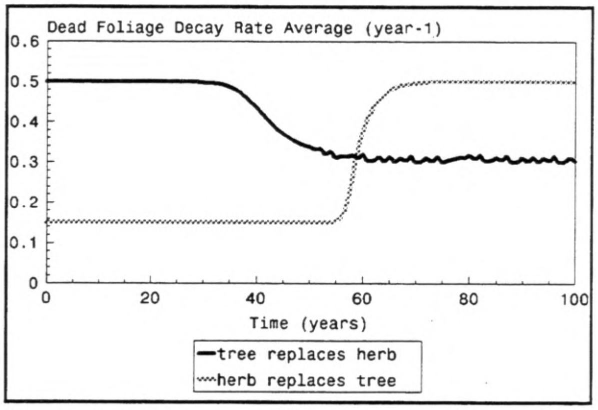

Figure 31. Example of response of changing substrate quality of dead foliage over succession.

Laboratory 1967) adjusted for the rates reported under natural conditions (Harmon et al. 1986).

The decomposition rate of each pool is dependent on the substrate quality of the inputs to that pool and the current substrate quality of the pool. The overall decomposition rate is a weighted average of the input and current stores. This has the dual effect of building in a system memory but allowing the decomposition rate to gradually change if the substrate quality of the inputs change (Figures 31 & 32).

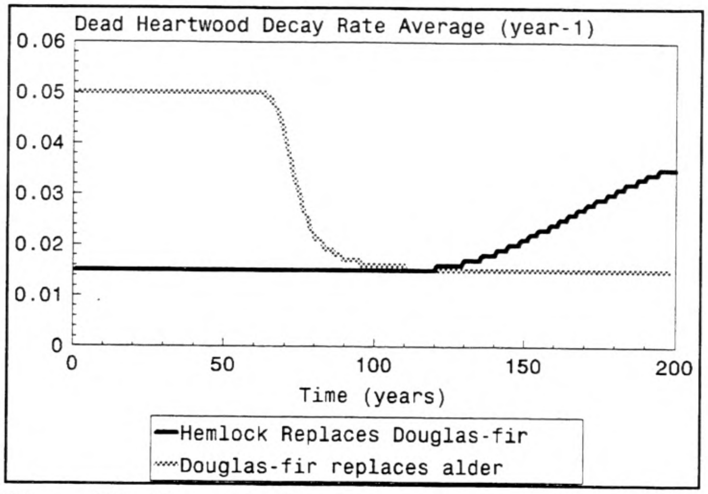

Figure 32. Change in heartwood decomposition rate caused by changes in dominant tree species over succession.

The first step is to calculate the weighted average decomposition rates of the inputs of each pool from the herb, shrub, lower tree, and upper tree layers so that the layers with the largest inputs have the greatest impact on the decomposition rate:

$$\text{InputDecayRate}\mathit{Pool} = \sum (\mathit{LayerPool}\text{Input} * \text{DecayRate}\mathit{LayerPart}) / \mathit{Pool}\text{Input}$$

where InputDecayRate*Pool* is the weighted average decomposition rate of the inputs to a detrital pool, *LayerPool*Input is the mass input of each plant part from a specific plant layer (e.g., herbs) to a detrital pool, *Pool*Input is the total input of all layers to a pool, and DecayRate*LayerPart* is the decomposition rate of a part for a layer at 10 C and when moisture is not limiting. For herb and shrub layers the latter parameter is fixed for the entire layer. For trees, however, this parameter is a function of the tree species occupying the particular tree layer. The values of DecayRate*LayerPart* are stored in the Decomp.prm file.

The second step is to calculate the weighted average decomposition rate from the average substrate quality of the inputs and the current material within the detrital pool. This step builds in a system memory and allows the decomposition rate of a detrital pool to change gradually when the substrate quality of the inputs change. Therefore one can not change the decomposition rate of a detrital pool unless the change in substrate quality of the inputs is continued. The weighted average decomposition rate of each detrital pool is:

$$\begin{aligned}\mathit{Pool}\text{DecayRateAvg} = {} & (\text{InputDecayRate}\mathit{Pool} * \mathit{Pool}\text{Input} \\ & + \text{Old}\mathit{Pool}\text{DecayRateAvg} * \mathit{Pool}) / (\mathit{Pool}\text{Input} + \mathit{Pool})\end{aligned}$$

where *Pool*InputDecayRate and *Pool*Input are as above, Old*Pool*DecayRateAvg is the weighted average decomposition of each detrital pool from the past year, and *Pool* is the last years mass of a particular detrital pool. An array of the values from the previous year containing Old*Pool*DecayRateAvg is stored and used to calculate the current value of *Pool*DecayRateAvg.

Detritus Decomposition Function

This function calculates the decomposition rate and mass of detritus lost from decomposition. Decomposition rate is calculated from the substrate effect (see Detritus Substrate Effect function above) and the effects of abiotic factors, temperature, solar radiation warming, and moisture as calculated in CLIMATE. The rate of decomposition losses from all the detrital pools is:

*Pool*Decay = *Pool*DecayRateAvg**Pool*AnnualAbioticDecayIndex

where *Pool*Decay is the realized decomposition rate of a detrital pool, *Pool*DecayRateAvg is the substrate quality determined rate when temperature is 10 C and moisture is not limiting, and *Pool*AnnualAbioticDecayIndex is the combined effects of temperature and moisture on decomposition as calculated in the AbioticDecayIndex function of CLIMATE.

The mass of detritus lost via decomposition in a year from a pool is :

*Pool*DecayLoss= *Pool*Decay*Pool

where *Pool*DecayLoss is the mass lost via decomposition, *Pool*Decay is the realized decomposition rate of a pool, and Pool is the mass of a detrital pool.

Soil Transfer Function

This function transfers mass from each detrital pool to the stable soil pool. This is designed to mimic the process of stable organic matter or carbon formation. In this version of the model there is no lag between the time of detrital inputs and the formation of stable soil. In other words, a proportion of each pool can form some stable organic matter each year. While it may actually take a number of years for this to happen for a given foliage, branch, or other piece of woody detritus, the model will simulate situations where detrital pools are not eliminated entirely by fire or other disturbances. Even if this is the case, the algorithm used will give reasonable results within a few years.

The first step is to calculate the transfer to the Stable Soil Organic Matter pools:

SoilTransfer*Pool*=SoilTransferRate*Pool**Pool

where SoilTransfer*Pool* is the mass transferred to the stable soil pool, SoilTransferRate*Pool* is the fraction of a pool transferred as defined in the DcayPrm.prm file and Pool is the mass of particular detrital pool.

Detrital Stores Function

This function is used to calculate the change in the mass of detrital stores each year. The balance for each detrital pool is the inputs minus the losses from decomposition and transfers to the stable soil pool. Losses from fire are calculated by SITEPREP. The overall rate of change for a detritus pool is:

Delta*Pool*=*Pool*Input -*Pool*DecayLoss-SoilTransfer*Pool*

where *Pool*Input is calculated in the Detritus Input function, *Pool*DecayLoss is calculated in the Detritus Decomposition function, and SoilTransfer*Poo*l is as defined above.

The mass in a give detrital pool for a given year is therefore:

Pool= Old*Pool* + Delta*Pool*

where Pool is the mass in a particular detrital pool, Old*Pool* is the value for the previous year, and Delta*Poo*l is as above.

CoarseWoodyDebris Function

Coarse woody debris (here called dead boles to follow the naming conventions established) is comprised of two detrital pools, dead sapwood and dead heartwood. These pools are kept separate so that as the stand gets larger the contribution of heartwood will increase. This allows substrate quality of the overall coarse wood pool to change even if the species of tree remains the same throughout succession.

The total coarse woody detritus stores are:

DeadBole=DeadSapWood+DeadHeartWood.

Stable Soil Function

This function controls the input and decomposition of stable soil organic matter or carbon. This represents a very stable pool in the model and should not change greatly over time unless the forest is removed for extensive periods. The intent of this function is not to consider all the factors that control stable soil fractions and predict the stores of stable soil carbon or organic matter *a priori*. Other models are more appropriate for these types of estimates. Rather the intent is to mimic the slow changes in stores in this pool.

Because the parameter SoilDecayRate is difficult to measure, this parameter may have to be changed for each particular situation. We recommend that SoilDecayRate be estimated by running the model in the single cell mode after setting the initial soil carbon value in the Simul.drv file. If the inputs of detritus to the stable soil are stable and the soil carbon approximates the store expected for particular soil, then the SoilDecayRate is probably correct. To see if inputs to the stable soil pool are constant one can examine the Mort.Dgn file. If the inputs are constant and the stable pool is increasing, then SoilDecayRate is probably too low. If the inputs are constant and the stable pool is decreasing, then SoilDecayRate is probably too high. The user should change the value of SoilDecayRate in theDcayParm.prm file until it converges on the target level of stable soil carbon.

Inputs to the stable soil pool are potentially transferred from all the detrital pools. We have parameterized this version of the model to receive inputs from the dead foliage, dead fine roots and dead coarse roots pools. The equation describing the inputs to the stable soil pool is the sum of all the various inputs from detrital pools:

SoilInput= $\sum$ (SoilTransfer*Pool)*

where SoilTransfer*Pool* is the transfer rate from each of the detrital pools as calculated in the Soil Transfer function.

As with the detrital pools, the decay rate of stable soil (SoilDecay) is a function of the substrate and abiotic effects:

SoilDecay=SoilDecayRate*StableSoilAnnualAbioticDecayIndex

where StableSoilAnnualAbioticDecayIndex represents the combined effects of temperature and moisture calculated by CLIMATE, and SoilDecayRate is the rate of decomposition of this pool at 10 C when moisture conditions are not limiting.

The overall rate of change for this pool is:

DeltaStableSoil=SoilInput-SoilDecay

The stores for this pool in a given year are:

StableSoil=OldStableSoil+DeltaStableSoil where OldStableSoil is the mass for the previous year and DeltaStableSoil is calculated as above.

Total Stores Function

This function calculates the total mass of dead pools (TotalDead) and the mass of dead carbon that is labile (DeadLabile). The latter represents the dead material most subject to change because of forest management. TotalDead is calculated as the total of all the detrital pools and stable soil, whereas LabileDead excludes the stable soil pool.

HARVEST

The purpose of module is to determine if a cell is to be harvested and to reallocate the carbon in the living and dead pools depending upon the type and utilization standards of the harvest used (Figures 33 & 34). The output variables of this module are used to modify the state variables in the GROWTH and the DECOMPOSE objects. Harvest is invoked the year a harvest is specified. Harvest calculations are made following the calculation of changes associated with normal growth and decomposition.

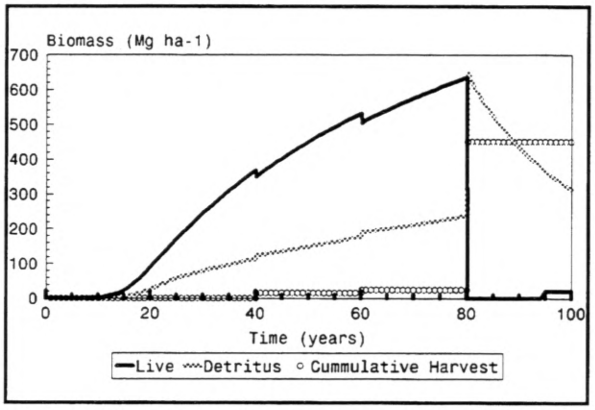

Figure 33. Example of effect of HARVEST on live and dead biomass when low utilization standards of harvest are practiced.

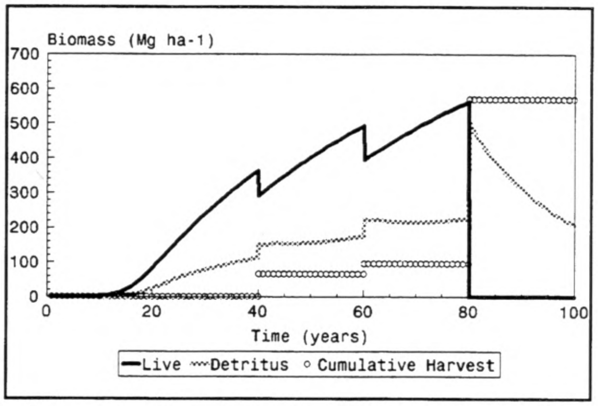

Figure 34. Example of the effect of HARVEST on live and dead mass when high utilization standards are practiced.

The utilization standards (i.e., fraction of the bole removed) for each type of harvest is defined by the Harvest.prm file. The schedule of harvests is given in the HarvInt.drv file. Finally, the pattern of cells that are cut in a given harvest cycle is specified in the CutPatt.drv file.

If a harvest activity is to occur on a cell in a given simulation year, then HARVEST determines which type of activity is to occur as defined by the HarvInt.drv file. Possible activities include: precommercial thinning, commercial thinning, and clear-cut harvest. These activities may be performed on the upper or lower tree layer separately or together. Precommercial thinning is defined as a thinning of the trees where all the bole material is left on the site as slash. In a commercial thinning, a proportion of the boles in a cell is removed. Finally, in a clear-cut all the bole material for a cell is cut. When the single cell mode of the model is used, the treatment occurs on that cell. When the multicell version of the model is used, it is possible for the treatment to occur on all the cells or a subset of cells depending upon the pattern indicated in the CutPatt.drv file. Thus specifying clear-cut harvest in the multicell version does not necessarily mean that all the cells are clear-cut.

All the harvest activities result in the production of detritus that is subtracted from the mass of each part in GROWTH and added to the detrital pools in DECOMPOSE. In addition, some of the bole material is removed as harvested mass.

The files used by this module are Harvest.prm,HarvInt.drv, and CutPatt.drv.

Convert Function

This function converts the parameters from the Harvest.prm file from percentages to proportions:

AmtCut=AmtCut/100

AmtTake=AmtTake/100

where AmtCut is the fraction of the tree bole volume that is cut and AmtTake is the fraction of the boles that are cut that is taken as harvested material.

Harvest Function

Once the type, timing, and pattern of a harvest treatment has been determined from the HarvInt.drv and CutPatt.drv files this function calculates the amount of sapwood and heartwood mass removed, the mass of sapwood and heartwood left in tops and stumps, and the mass of other detritus or slash created by the harvest. Regardless of the type of harvest specified, the mass of plant parts remaining after harvest is calculated as:

*Part*Remaining=(1- AmtCut)**Part*Old

where

*Part*Remaining and *Part*Old are the masses of plant parts after and before the harvest.

Sapwood and heartwood can be removed from the site during harvest. The mass of sapwood and heartwood that is removed (*Part*Taken) from a cell is calculated as:

*Part*Taken= AmtCut*AmtTake**Part*

where AmtCut is the proportion of the tree biomass cut and AmtTake is the proportion of the bole mass that is harvested and exported from the site as forest products, and *Part* is either sapwood or heartwood mass. In most cases AmtTake for precommercial thinning is set to zero.

We have used the convention that the input of detritus mass associated with harvest is named for the detritus pool with the addition of Harv (e.g., sapwood left to decompose after harvest is called DeadSapwoodHarv). The amount of sapwood and heartwood mass added to the DeadSapwood and DeadHeartwood pools due to harvesting is calculated as:

*Pool*Harv = AmtCut*(1-AmtTake)**Part*

where *Pool* is either DeadSapwood or DeadHeartwood, and *Part* is either Sapwood or Heartwood mass, respectively.

For other plant parts such as branches and coarse roots, the model assumes there is no export from the site. The mass of the non-bole parts transferred to their appropriate dead pool by commercial thinning are calculated as:

*Pool*Harv=AmtCut**Part*

where *Pool* is the detrital pool the material is being added to (i.e., DeadFoliage, DeadFineRoots, DeadBranch, and DeadCoarseRoots) and *Part* is the corresponding plant part mass (i.e., Foliage, FineRoots, Branches, and CoarseRoots).

Volume Function

This function converts the mass of boles harvested from a cell for a given year to wood volume. The volume of bole wood removed in harvest is estimated from the sapwood and heartwood mass removed and the fraction of boles in wood (WoodPer), and the wood density (WoodDen) for the given species harvested in a cell. The parameters WoodPer and WoodDen are stored in the Growth.prm file.

The total mass removed in boles for a tree layer in a cell is:

Harvest=SapwoodTaken + HeartwoodTaken

The mass of wood (Wood) in the harvested boles is:

Wood=Harvest*WoodPer/100

where WoodPer is the percentage of the bole mass that is wood as opposed to bark (Wilson et al.1987). The volume of wood (HarvVol) is calculated by dividing the wood mass (Wood) by the wood density (WoodDen):

HarvVol=Wood/WoodDen

The values of wood density for each species are based on Marglin and Wahlgren (1972) and Wilson et al. (1987).

BURNKILL

This module determines the amount of live vegetation that is killed and consumed by a fire. The purpose of this module is to reduce the amount of live carbon in the GROWTH module and to transfer some of this material to the DECOMPOSE module as fire-killed detrital inputs. Not all the live vegetation killed by fire is necessarily transferred to detritus; some is consumed by the fire itself. BURNKILL is invoked the year a fire is specified, but the calculations occur after normal growth and decomposition calculations have been made for that year. If a harvest has been specified for a year, then the Burnkill calculations are performed after the harvest calculations.

The type of fire may be a management burn or wildfire. The amount that the live plant parts and layers is reduced is described in the BurnKill.prm file. The BurnKill.prm file is set up so that as the fire intensity increases from light to hot the fraction of each of the vegetation layers (herbs, shrubs, upper trees, and lower trees) killed by fire increases. The fraction of plant material that is consumed by fire also increases with fire intensity. Above- and below-ground plant parts can be consumed by fire to different degrees. We have set the parameters so that below-ground parts have less material consumed than above-ground parts for a given fire intensity. The user selects the timing and type of burn in the HarvInt.drv or the WFireInt.drv files.

BurnKill Function

This function determines the proportion of each part of each layer remaining after a fire occurs. The first step is to determine when and what type of fire occurs in a cell as determined by the HarvInt.drv file or by the WFireInt.drv file. The site preparation fire is set to occur the year of a harvest. Site preparation fires may occur after thinning, although we usually assume these types of fires are not used. As with SITEPREP, only one of three types of fires can occur in a given year: light, medium or hot fires.

The fraction of the above-ground live mass of a part of a layer surviving (Surv*Part*) after a fire is:

$$\mathrm{Surv}\mathit{Part}=(1-\mathrm{AboveKill}/100)*\mathit{Part}$$

where AboveKill is the percentage of above-ground parts killed by the fire (determined from the BurnKill.prm file), and *Part* is the mass of the above-ground part (i.e., foliage, branches, sapwood, and heartwood) in question. These calculations are performed for each of the layers in a cell.

The fraction of the below-ground live mass of a part surviving (Surv*Part*) after a fire is:

Surv*Part*=(1-BelowKill/100)**Part*

where BelowKill is the fraction of below-ground parts killed by the fire (determined from the BurnKill.prm file), and *Part* is the mass of the below-ground part (i.e., fine roots and coarse roots) in question. These calculations are performed for each of the layers in a cell.

The mass of above- and below-ground parts killed (Kill*Part*) is calculated as:

Kill*Part*=*Part*-Surv*Part*

where *Part* refers to a specific plant part of a layer in a cell. This quantity is deducted from the live mass of the parts for each layer of each cell in GROWTH.

Consume Function

This function calculates the of mass plant parts that is consumed by fire. Above- and below-ground parts have different portions of parts consumed by fire. For above-ground parts the mass consumed (Consum*Part*) is:

Consum*Part*=AboveBurn*Kill*Part*/100

where AboveBurn is the percentage of the above-ground parts that are killed by fire that are combusted (determined from the BurnKill.prm file), and *Part* is the mass of the above-ground part (i.e., foliage, branches, sapwood, and heartwood) in question. These calculations are performed for each of the layers in a cell.

For below-ground parts the mass consumed (Consum*Part*) is:

Consum*Part*=BelowBurn*Kill*Part*/100

where BelowBurn is the percentage of the below-ground parts that are killed by fire that are combusted (determined from the BurnKill.prm file), and *Part* is the mass of the below-ground part (i.e., foliage, branches, sapwood, and heartwood) in question. These calculations are performed for each of the layers in a cell.

The mass of above- and below-ground parts added to the appropriate detrital pool in DECOMPOSE (BurnInput*Pool*) is calculated as:

BurnInput*Pool*=Kill*Part*-Consum*Part*

where *Pool* refers to a specific detrital pool in a cell. This quantity is added to the appropriate detrital pool of each cell in DECOMPOSE.

SITEPREP

The purpose of this function is to reduce the amount of dead material in the DECOMPOSE module to reflect the losses caused by fire. The type of fire may be a management broadcast burn or a wildfire. SITEPREP is invoked the year a fire is specified, but the calculations occur after normal growth and decomposition calculations have been made for that year. If a harvest has been specified for a year, then the SITEPREP calculations are performed after the harvest calculations. SITEPREP only reduces the parts of detrital pools that existed before the fire in question occurs. Thus detritus that is created the same year from harvest or death from fire are not reduced by BURNKILL.

The amount that the detrital pools are reduced is described in the SitePrep.prm file. The SitePrep.prm file is set up so that as fire intensity increases from light to hot, the fraction of each of the above-ground detrital pools removed by fire increases. In contrast, it is assumed that the dead coarse roots and the stable soil pools do not decrease when there is a fire. This assumption is not "hardwired" and the user is able to have carbon lost from these pools by changing the SitePrep.prm file. The user selects the timing and type of burn in the HarvInt.drv or the WFireInt.drv file.

SitePrep Function

This function determines the proportion of each detrital pool remaining after a fire occurs. The first step is to determine when and what type of fire occurs in a cell as determined by the HarvInt.drv file or by the WFireInt.drv file. The site preparation fire occurs the same year as the harvest. One can have site preparation fires following any type of harvest. We assume that site preparation fires, however, will usually follow clearcutting but not thinning. One of three types of fires can occur in a given year: light, medium or hot fires. To calculate the amount removed in each of the detrital pools after fire (*Pool*FireLoss), the fraction remaining is multiplied by the mass of the pool:

$$Pool\mathrm{FireLoss}=(1-Burn\mathrm{Remaining}/100)*Pool$$

where *Pool* is the mass of a given detrital pool (i.e., dead foliage, dead branches, dead sapwood, dead heartwood, dead fine roots, dead coarse roots, or stable soil), *Burn*Remaining is the percent remaining after a fire of type *Burn*. The latter parameter is determined from the SitePrep.prm file.

If a fire does not occur in a given cell on a given year then

$$Pool\mathrm{FireLoss}=0.$$

The detritus pool mass is then reduced to account for these fire losses:

*Pool*New=*Pool*Old-*Pool*FireLoss

where *Pool*New and *Pool*Old are the detritus pool mass after and before the fire, respectively.

NEIGHBOR

The purpose of this module is to simulate the interaction between cells regarding light. The main interaction between cells is therefore one of shading. The degree of shading is determined by the relative heights of trees in cells and the distance between cells. No attempt is made to realistically model the height distribution or profile of foliage in canopies in NEIGHBOR. Rather, it is assumed that foliage extends from the ground to the tree top and that foliage mass is evenly distributed over this height. While real foliage profiles are more complex, this simplifying assumption represents many common situations such as well stocked stands. It is most likely to have problems in situations where tree stocking is very low or cell to cell variation in tree heights is high.

There are two aspects of shading considered: 1) the blocking of indirect or diffuse radiation and 2) the blocking of direct radiation. Diffuse radiation can be blocked on all sides, whereas direct radiation can be blocked on the east, southeast, south, southwest, and west facing directions.

The degree of blocking of radiation inputs for direct and diffuse radiation is based on the height difference between the cell in question and cells along 8 different transects. The height is estimated from the age of the upper tree layer in each cell.

The cell arrangement will be as a rectangular grid (Figure 35). This means that each cell will have four immediate neighbors. The distance across a cell (CellWidth) will be 20 m and represents a horizontal distance. The slope corrected area represented by each cell is therefore fixed. All cells will be referenced using two numbers to indicate their position on the X and Y coordinates. These are RowNum and ColNum, respectively. "Looking" uphill, Cell 1,1 will be in the uppermost left corner of the stand. This means the direction the sides of the cells face is across and up and down slope. The direction

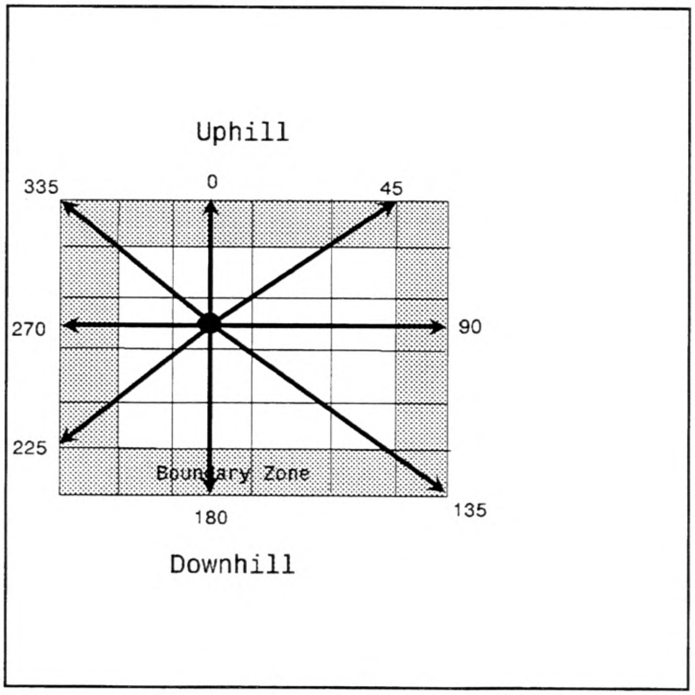

Figure 35. Arrangement of cells in STANDCARB multicell version.

the sides face, with respect to true north will therefore depend on the aspect of the stand.

In addition to the simulated stand, the height of a boundary forest is followed (Figure 36). The boundary forest is basically the surrounding stand. Its height must be followed and used to shade cells on the edge of the simulated stand to avoid unrealistic boundary effects.

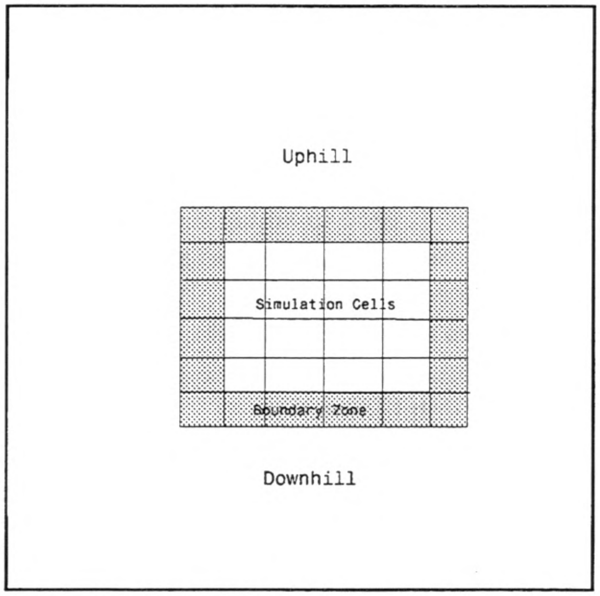

Figure 36. Relationship of boundary cells to simulation cells in multicell version of STANDCARB.

The height of the tree layer is determined by parameters described in the Growth.prm file. NEIGHBOR also uses the Radiate.drv file to calculate the height of the sun along the 5 transects closest to the path the sun follows during the yearly average day. Finally it depends on the Locate.drv file to determine the relative elevations of the cells to each other and the sun from the slope and aspect.

Boundary Function

This function is invoked once each simulation and is used to define the location and condition of the forest surrounding the simulated stand. As with all models that simulate shading effects, STANDCARB must address the so-called boundary problem. This is caused by the fact that cells respond to shading from surrounding cells, but on the boundaries the shading effect is ambiguous. Is the surrounding stand, for example, shorter or taller or the same as the simulated stand? Each boundary condition could lead to different responses of the simulated stand. To avoid this problem the user has to select the age of the surrounding stand. There are three options for the boundary forest:

1) No forest. If this selected then the tree height and age in the surrounding boundary cells is set to zero. This would be most likely to used to simulate a remnant forest surrounded by agriculture land or development.

2) Old-growth forest. If this is selected then the height in the surrounding boundary cells is set to the maximum height (HeightMax) of the dominant tree species (see the Growth.prm file). This situation would best match a staggered setting cutting pattern.

3) The same age as the simulated stand. If this is selected then the height is increased assuming the age of the forest in the surrounding cells is the same as the average of the trees in the simulated stand. The height is calculated as in the Tree Height function below. This situation would be used to simulate a stand with "infinite" extent.

The two numbers defining the location of the boundary cells are calculated from the number of rows and columns selected by the user. The upper boundary forest location is defined by using -1 for RowNum, the lower most boundary forest is defined by adding 1 to the highest RowNum of the simulated stand, etc.

Direction Function

This function is used to adjust the angle of the transect lines used to estimate shading effects. These lines are used to sample the angle between a particular cell and its surrounding cells (Figure 24). With respect to the uphill direction, the angles of the transect lines are 0, 45, 90, 180, 225, 270, and 315 degrees. To estimate the effects of removing direct radiation, these transect lines must be referenced to the true azimuth and not the uphill direction.

The first step in making this adjustment is to estimate the offset (Offset) between the uphill direction and south:

Offset=Aspect-180

The corrected transect line angle in radians is:

CorrectedLineAngle=0.0175*(Offset+LineAngle)

where LineAngle is the direction the transect line faces with respect to the uphill direction (0, 45, 90, 135, 180, 225, 270, or 315).

Local Elevation Function

This function determines the local elevation differences of the cells from the slope steepness. Assuming that a stand is always rectangular in shape, the rows of cells will determine how far one has traveled in horizontal distance in the uphill direction. Assuming that the last row is the lowest point of the stand the relative elevation of the cells in a row (*Row*RelElev) is:

*Row*RelElev=CellWidth*(NumRows-RowNumb)*(SlopeSteep/100)

whereCellWidth represents the maximum crown width of a mature tree, NumRows is the number of rows in a stand, RowNumb is the row number in question, and

SlopeSteepness is the slope steepness of the site in percent as defined by the Locate.drv file.

TreeHeight Function

The height of the crown in a cell will be determined from the age of the upper canopy layer. A Chapman-Richards equation will be used to predict the height from the age since planting of the upper canopy layer:

$$\text{TreeHeight}=\text{HeightMax} * (1 - \exp[-\text{HeightRate}*\text{Age}])^{\text{HeightShape}}$$

where HeightMax is the maximum height of a species, HeightRate is the rate at which the maximum is reached, and HeightShape is the parameter that reduces height growth early in the life of a tree. These parameters are stored in the Growth.prm file. Age will be the time since the upper tree layer was planted in a cell. For the boundary cells, Age will represent one of the three conditions outlined above under the Boundary Function .

In the case of cells where a lower tree layer replaces an upper tree layer, the age of the new upper tree layer must be adjusted. Setting the age to zero when the tree layer replacement occurs will underestimate the height, because the lower tree layer may been growing slowly under the upper tree layer for some time. Conversely using the time since planted a lower tree was planted would give that layer too much height. Therefore when a lower tree layer replaces an upper tree layer the age will be set at 25 years and then incremented as for the original upper tree layer (see DIEOUT).

TotalHeight Function

This function is used to determine the total height of the trees in cells including the effects of topography. The total height difference between two cells is:

$$\text{TotalHeight}=\text{TreeHeight}+\text{RelElev}\mathit{Row}$$

Cell Select Function

This function is used to establish an array of cells that need to be considered for shading effects. The idea is that although each cell has the potential to shade every other cell, only a subset of cells will lie along the transect directions that will be sampled (see Direction function above). For each cell the surrounding cells that need to be examined will depend upon the transect line being considered. To avoid confusion we will refer to the transect lines by the direction they face with respect to the uphill direction.

For the 0 line the cells to be considered are selected by keeping ColNum constant and decreasing the RowNum by 1 until a boundary cell is reached. For the 180 line the cells to be considered are selected by keeping ColNum constant and increasing the RowNum by 1 until a boundary cell is reached. For the 90 line the cells to be considered are selected by keeping RowNum constant and increasing the ColNum by 1 until a boundary cell is reached. For the 270 line the cells to be considered are selected by keeping RowNum constant and decreasing the ColNum by 1 until a boundary cell is reached.

For lines on the diagonal the method is slightly more complex. For the 45 line the cells are selected by decreasing the RowNum and increasing the ColNum by 1 until a boundary cell is reached. For the 225 line the cells are selected by increasing the RowNum and decreasing the ColNum by 1 until a boundary cell is reached. For the 135 line the cells are selected by increasing both the ColNum and RowNum by 1 until a boundary cell is reached. Finally, for the 315 line the cells are selected by decreasing bot the RowNum and ColNum by 1 until a boundary cell is reached.

Distance Function

This function determines the horizontal distance between two cells. This variable is then used to compute the angle between the canopies of two cells to determine shading effects. The first step is to calculate the difference in X and Y coordinates for the cells:

ColDiff=ColNum2-ColNum1

RowDiff=RowNum2-RowNum1

where these are the row and column numbers for cells 1 and 2. The horizontal distance between the centers of the cells is:

CellDist= Sqrt [CellWidth*(ColDiff^2 +RowDiff^2)]

DiffuseShading Function

The purpose of this function is to determine the fraction of the sky that is obscured by the trees in surrounding cells. The angle (in radians) between the top of tree layer in the cell of question and the 8 adjacent cells which form the largest angle in the eight transects will be computed as:

DiffuseShadeAngle=arctan [(TotalHeightCell2-TotalHeightCell1)/CellDist] where TotalHeightCell2 is the height of the upper tree layer in the adjacent cell, TotalHeightCell1 is the height of the upper tree layer in the cell in question and CellDist the distance from the center of one cell to the cell forming the largest angle.

The angle of the sky open to diffuse light would therefore be:

$$DiffuseOpenAngle = 1.57 - DiffuseShadeAngle$$

After DiffuseOpenAngle is calculated for each of the 8 transects, they are summed up and divided to estimate the fraction of the sky that is obscured by adjacent trees:

$$DiffuseOpen = \sum (DiffuseOpenAngle / 12.5664)$$

This number is then used to reduce the DiffuseSolRadSlope that can enter a plot.

DirectShading Function

This function estimates the effects of cells lying on the transects to the east, southeast, south, southwest, and west on the input of direct radiation to the cell. This function uses the angles calculated in the DiffuseShading Function to estimate the amount of direct radiation blocked. These angles are compared to mean altitude angle of the sun along each transect. The mean altitude angle of the sun on each transect is calculated from the transect direction and the mean altitude angle of the sun when it is due south (or solar noon). This variable is stored in the Radiation.drv file.

The first step is to calculate the mean solar altitude angle for each transect:

$$TransectSolarAltAngle = - SolarAltAngleSouth * \cos (CorrectedLineAngle*ExpFactor+PhaseAdj)$$

where SolarAltAngleSouth is the solar altitude angle when the sun is due south, CorrectedLineAngle is the angle the transect faces (see Direction function above), ExpFactor and PhaseAdj are factors used to correct for the fact the sun does not always rise or set at due east. ExpFactor is calculated from the average azimuth angle when the sun rises (SunriseAzimAngle):

$$ExpFactor = (SunriseAzimAngle - 180)/90$$

and is used to rescale the angle between south and the azimuth angle of the sunrise. PhaseAdj is used to adjust the phase of the cosine wave so that the highest value is always at 180 degrees (due south). It is calculated as:

PhaseAdj=0.0349* (90-SunriseAzimAngle)

TransectSolarAltAngle is then compared to the angle between the heights of the cell in question (DirectShadeAngle) and the adjacent cell where:

DirectShadeAngle= DiffuseShadeAngle

if the DiffuseShadeAngle is greater than or equal to 0 and

Direct ShadeAngle=0

if the DiffuseShadeAngle is less than 0.

If the solar altitude angle is smaller than or equal to the DirectShadeAngle, then the value of a variable indicating the direction (e.g., E, SE, S, SW, W) will be set to 1. If the sun angle exceeds the tree height angles then this variable is set equal to 0. To calculate the fraction of the direct light reaching the cell these variables are weighted by their importance in adding radiation:

DirectOpen=1-E*0.035 +SE*0.27 + S*0.39 + SW*0.27 + W*0.035

where E., SE, S, SW, and W indicate the effect of direct radiation blocking from those directions. For example, if direct light is blocked from all the directions then DirectOpen is zero. If on the other hand direct light is blocked from just the south then DirectOpen is 0.39.

The light allowed to enter a cell is calculated from the fraction of diffuse and direct light passing through the adjacent cells and the amount of radiation specified by the Radiate.drv file:

LightIn=[(DirectOpen*DirectSolarRad) + (DiffuseOpen*DiffuseSolRad)]/SolRad

where DirectSolarRad, DiffuseSolRad, and SolRad are the mean daily diffuse, direct, and total solar radiation, respectively as specified by the Radiate.drv file.

INPUT AND OUTPUT FILES

INPUT FILES

PARAMETER FILES

This section describes the files containing the parameters needed to run the model. For the most part these files should require minor adjustments to make the model simulate most common situations. All the files that contain parameters end with the extension **PRM**. The parameter files needed to run STANDCARB are shown in Table 1.
For each file the parameters are defined and the units indicated. The file format in terms of columns is flexible, however, the parameters must be listed in the order shown.

Finally, an example of each file is given.

Table 1. List of parameter files required to run the STANDCARB model. Note that the UNIX version is case sensitive; therefore both the file name and extension must be as shown in the listing.

File Name	Purpose
Estab.prm	sets rates that layers establish
TreeReg.prm	defines which tree species can establish
Growth.prm	sets species attributes of growth
GrowParm.prm	sets layer attributes of growth
Mort.prm	sets species attributes of litter formation and mortality
Decomp.prm	sets species attributes of decomposition
DcayParm.prm	sets detritus pool attributes of decomposition
BurnKill.prm	sets levels of fire mortality for each plant layer
SitePrep.prm	sets levels of fuel reduction for each detritus pool
Harvest.prm	defines the level of removal given a harvest
Soil.prm	sets characteristics of soil texture classes
SiteIndx.prm	sets the level of productivity for a site index of a tree species

Estab.prm

This file indicates the probability that the different life forms (e.g., herbs, shrubs, and trees) have of entering a cell.

There are four regeneration scenarios parameterized: 1) NF-natural fast, 2) NS-natural slow, 3) AF- artificial fast, and 4) AS- artificial slow. Probabilities for each regeneration scenario are given with and without an upper tree layer. If an upper tree layer is present then the Closed probabilities are used. If the upper tree layer is not present then the Open probability is used. Note that for any regeneration scenario and upper tree layer status (i.e., Open or Closed), the probabilities can not sum to a value exceeding 1.0.

The parameters in order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 1 indicates this is the Estab.prm file.

Layer: refers to the layer of living vegetation. Three names are valid: herb, shrub, or tree. Tree is used to indicate the parameters for upper and lower tree layers.

EstOpenNF: establishment probability for natural open, fast regeneration (year^{-1}). For trees this would apply to the upper tree layer.

EstClosedNF:establishment probability for natural closed, fast regeneration (year^{-1}). For trees this would apply to the lower tree layer.

EstOpenNS:establishment probability for natural open, slow regeneration (year^{-1}). For trees this would apply to the upper tree layer.

EstClosedNS:establishment probability for natural closed, slow regeneration (year^{-1}). For trees this would apply to the lower tree layer.

EstOpenAF: establishment probability for artificial open, fast regeneration (year^{-1}). For trees this would apply to the upper tree layer.

EstClosedAF: establishment probability for artificial closed, fast regeneration (year^{-1}). For trees this would apply to the lower tree layer.

EstOpenAS: establishment probability for artificial open, slow regeneration (year^{-1}). For trees this would apply to the upper tree layer.

EstClosedAS: establishment probability for artificial closed, slow regeneration (year^{-1}). For trees this would apply to the lower tree layer.

Example Estab.prm file:

Estab.prm

Model, File, Layer, EstOpenNF, EstClosedNF, EstOpenNS, EstClosedNS, EstOpenAF, EstClosedAF, EstOpenAS, EstClosedAS

```
ML02 1  Herb   0.500 0.250 0.600 0.300 0.200 0.250 0.600 0.300
ML02 1  Shrub  0.300 0.150 0.300 0.150 0.200 0.150 0.300 0.150
ML02 1  Tree   0.200 0.050 0.030 0.050 0.600 0.050 0.100 0.050
```

TreeReg.prm

This file is used to determine the tree species that can grow on a given site. These parameters are specific to a given location within the Pacific Northwest.

The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 2 indicates this is the TreeReg.prm file.

Species: the species or understory layer that the parameters describe. Species abbreviations are after Garrison and can be in any order.

LightMax: the maximum amount of light a species can establish under (percent of full sunlight).

LightMin: the minimum amount of light a species can establish under (percent of full sunlight).

DDayMax: the degree day maximum that a species can establish under (degrees C).

DDayMin: the degree day minimum that a species can establish under (degrees C).

TreeSoilMin: minimum water potential under which a tree species can establish itself. If this value is exceeded for more than 9 months of the year then a species can not establish itself in a cell because the soil is too moist (Mpascals).

TreeSoilMax: maximum water potential that a tree species can tolerate during establishment (Mpascals).

Sprout: ability of a tree specie to sprout with 0 meaning no sprouting and 1 meaning species can sprout.

CACR: the local abundance of a tree species in the California Coast Range with 0 being absent to 99 being very abundant.

CACW: the local abundance of a tree species in the west slope of the California Cascade Range with 0 being absent to 99 being very abundant.

ORCW: the local abundance of a tree species in the west slope of the Oregon Cascade Range with 0 being absent to 99 being very abundant.

ORCE: the local abundance of a tree species in the east slope of the Oregon Cascade Range with 0 being absent to 99 being very abundant.

ORCR: the local abundance of a tree species in the Coast Range of Oregon with 0 being absent to 99 being very abundant.

WACW: the local abundance of a tree species in the west slope of the Washington Cascade Range with 0 being absent to 99 being very abundant.

WACE: the local abundance of a tree species in the east slope of the Washington Cascade Range with 0 being absent to 99 being very abundant.

OTHR: the local abundance of a tree species in any other region as determined by the user with 0 being absent to 99 being very abundant.

Example Treereg.prm file:

Treereg.prm

Model, File, Species, Lmax, Lmin, DDMax, DDMin, TSMin, TSMax, Sprout, CACR, CACW, ORCW, ORCE, ORCR, WACW, WACE, OTHR

```
ML02 2   Abam  0.80 0.05  2200   400   0.10 2.0 0   0   0 10   0   0 10   0   0
ML02 2   Abco  0.90 0.10  2640   990   0.10 2.5 0   0  10  1   0   0   0   0   0
ML02 2   Abgr  0.90 0.10  2640   990   0.10 2.0 0   0   0  2  10   2   0  10   0
ML02 2   Abla  1.00 0.10  1200   350   0.10 1.8 0   0   0  5   5   0   5   5   0
ML02 2   Abpr  1.00 0.50  1854   885   0.10 2.0 0   0   0 10   0  10  10   0   0
ML02 2   Abma  1.00 0.50  1854   885   0.10 2.0 0   0   0  0   0   0   0   0   0
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

ML02 2   Pisi  1.00 0.50  2000   400   0.05 1.5 0   2   0  0   0  10   2   0   0
ML02 2   Potr  1.00 0.90  3500   900   0.05 1.0 0   0   0  5   0   5   5   0   0
ML02 2   Prem  1.00 0.90  3500   600   0.10 2.0 1   0   0  7   0   0   1   0   0
ML02 2   Psme  1.00 0.90  3500   600   0.20 2.0 0   5   2 10   5  10  10   5   0
ML02 2   Quga  0.90 0.50  2880   975   0.20 2.5 1   5   0  1   0   0   0   0   0
ML02 2   Sese  1.00 0.25  2500   600   0.10 1.5 1  10   0  0   0   0   0   0   0
ML02 2   Thpl  0.80 0.25  2480   675   0.05 1.5 0   0   0  5   0   3   5   0   0
ML02 2   Tshe  0.80 0.05  2480   760   0.10 1.7 0   5   0 10   0  10  10   0   0
ML02 2   Tsme  1.00 0.25  1475   555   0.10 1.7 0   0   0 10  10   0   0   0   0
```

Growth.prm

This file contains the species and understory parameters to describe the growth of leaves, branches, sapwood, heartwood, and roots.

The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 3 indicates this is the Growth.prm file.

Species: the species or understory layer that the parameters describes. Species abbreviations are after Garrison and can be in any order. Herb and shrub are included as non-tree species.

LightCompPoint: light compensation point for a species of tree or understory layer (%).

LightExtCoeff: light extinction coefficient for a species of tree or understory layer (ha Mg^{-1}). This is the point at which additional leaves can not survive.

FoliageProdRateMax: maximum rate of foliage production (dimensionless). This parameter is the rate leaves of a species can create more leaves.

FineRootFoliageRatio: fine root mass to foliage mass ratio (dimensionless).

SapLive: fraction the sapwood that is alive (% sapwood volume).

RateHeartWoodForm: rate of heartwood formation from sapwood ($year^{-1}$).

BranchBoleRatio: branch mass to bole mass ratio (dimensionless). Used to allocate production to branches.

CoarseRootBoleRatio: coarse root mass to bole mass ratio (dimensionless). Used to allocate production to coarse roots.

TempMin: minimum temperature for net photosynthesis of a species or life form (C).

TempMax: maximum temperature for net photosynthesis of a species or life form (C).

WoodPer: the percentage of the bole that is wood (%).

WoodDen: the density of wood in the bole (Mg m^{-3}).

HeightMax: the maximum height of a tree species (m).

HeightRate: the rate the maximum height of a tree species is reached as a function of age ($year^{-1}$).

HeightShape: introduces a lag in the height growth curve (dimensionless).

Example Growth.prm file:

Growth.prm

Model, File, Species, LightCompPoint, LightExtCoeff, LeafProdRateMax, FileRootLeafRatio, SapLive, RateHeartWoodForm, BranchBoleRatio, CoarseRootBoleRatio, TempMin, TempMax, WoodPer, WoodDen, HeightMax, HeightRate, HeightShape

```
ML02 3 Herb   50 0.23 2.00 0.75  0.00 0.000 0.000 0.000  0 37   0.0 0.00   1 0.150  1.0
ML02 3 Shrub  30 0.40 1.20 0.50  0.00 0.000 1.500 1.500  0 37   0.0 0.00   2 0.075  2.0
ML02 3 Abam   10 0.15 0.50 1.00  6.60 0.039 0.500 0.750 -2 35  90.0 0.45  55 0.015  2.0
ML02 3 Abco   10 0.15 0.50 1.00  9.50 0.039 0.500 0.770  0 37  90.0 0.45  70 0.015  2.0
ML02 3 Abgr   10 0.15 0.50 1.00  6.70 0.039 0.500 0.770  0 37  90.0 0.45  70 0.015  2.0
ML02 3 Abla   10 0.15 0.50 1.00  5.70 0.039 0.900 1.200 -5 32  90.0 0.45  40 0.015  2.0
ML02 3 Abpr   10 0.15 0.50 1.00  6.60 0.039 0.350 0.720 -2 35  90.0 0.45  70 0.015  2.0
ML02 3 Abma   10 0.15 0.50 1.00  6.60 0.039 0.480 0.650 -2 35  90.0 0.45  70 0.015  2.0
ML02 3 Acma   20 0.32 0.50 1.00 18.50 0.010 0.220 0.380  0 37  90.0 0.45  40 0.015  2.0
ML02 3 Alru   20 0.32 0.50 1.00 13.70 0.010 1.500 0.550  0 37  90.0 0.45  40 0.050  2.0
ML02 3 Arme   20 0.32 0.50 1.00 13.70 0.059 0.850 0.950  2 39  90.0 0.45  25 0.050  2.0
ML02 3 Cach   20 0.32 0.50 1.00 12.20 0.059 0.850 0.900  2 39  90.0 0.45  35 0.050  2.0
ML02 3 Cade   10 0.15 0.50 1.00  8.90 0.105 0.500 1.000  2 39  90.0 0.45  60 0.015  2.0
ML02 3 Lide   20 0.32 0.50 1.00 12.20 0.059 0.900 1.000  2 39  90.0 0.45  40 0.050  2.0
ML02 3 Pico   20 0.15 0.50 1.00  5.70 0.024 0.350 0.900 -2 35  90.0 0.45  30 0.015  2.0
ML02 3 Pila   10 0.15 0.50 1.00  5.70 0.059 1.900 0.900  0 37  90.0 0.45  75 0.015  2.0
ML02 3 Pimo   10 0.15 0.50 1.00  6.60 0.059 1.900 0.900 -2 35  90.0 0.45  60 0.015  2.0
ML02 3 Pipo   20 0.15 0.50 1.00  6.80 0.011 0.330 0.570  0 39  90.0 0.45  60 0.015  2.0
ML02 3 Pien   10 0.15 0.50 1.00  5.90 0.043 0.400 0.850 -2 35  90.0 0.45  30 0.015  2.0
ML02 3 Pisi   10 0.15 0.50 1.00  7.30 0.039 0.350 0.800  0 37  90.0 0.45  90 0.015  2.0
ML02 3 Potr   20 0.32 0.50 1.00  9.60 0.059 0.500 0.500  0 37  90.0 0.45  45 0.050  2.0
ML02 3 Prem   20 0.32 0.50 1.00 16.40 0.059 0.500 0.500  0 37  90.0 0.45  25 0.075  2.0
ML02 3 Psme   10 0.15 0.50 1.00  7.40 0.059 0.250 0.770  0 37  90.0 0.45  85 0.015  2.0
ML02 3 Quga   20 0.32 0.50 1.00 30.00 0.059 0.950 1.250  2 39  90.0 0.45  25 0.015  2.0
ML02 3 Sese    5 0.15 0.50 1.00  7.90 0.102 0.250 0.770  0 37  90.0 0.45  99 0.015  2.0
ML02 3 Thpl   10 0.15 0.50 1.00  6.90 0.102 0.550 1.500  0 37  90.0 0.45  60 0.015  2.0
ML02 3 Tshe    5 0.15 0.50 1.00  8.80 0.022 0.850 0.650  0 37  90.0 0.45  80 0.015  2.0
ML02 3 Tsme   10 0.15 0.50 1.00  8.80 0.022 0.850 0.650  0 37  90.0 0.45  35 0.015  2.0
```

GrowParm.prm

This file is used to describe the response of the living layers to temperature. The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 4 indicates this is the GrowParm.prm file.

Layer: refers to the layer of living vegetation. Tree is used to indicate the parameters for upper and lower tree layers.

Q10Foliage: rate foliage respiration increases with 10 C increase (dimensionless).

RespFoliage10: respiration rate of leaves at 10 C (year^{-1}).

Q10FineRoot: rate fine root respiration increases with 10 C increase (dimensionless).

RespFineRoot10: respiration rate of fine roots at 10 C (year^{-1}).

Q10Sapwood: rate sapwood respiration increases with a 10 C change in temperature (dimensionless).

RespSW10: respiration rate of sapwood at 10 C (year $^{-1}$). Based on 5% of the sapwood being alive; species are adjusted from this rate based on the SapLive parameter in Growth.prm.

Q10Branch: rate branch respiration increases with a 10 C change in temperature (dimensionless).

RespBranch10: respiration rate of branches at 10 C (year $^{-1}$).

Q10CRoot: rate coarse root respiration increases with a 10 C change in temperature (dimensionless).

RespCRoot10: respiration rate of coarse roots at 10 C (year $^{-1}$).

InitialFoliageMass: mass of leaves that is added to Foliage when a layer is planted (Mg ha^{-1}).

CanIntCst: the ratio of the mass of leaves to the amount of canopy interception (mass^{-1}).

BoleGrowthEffic: the bole growth efficiency in terms of mass of sapwood produced per unit mass of foliage when moisture and temperature are not limiting (dimensionless).

Example GrowParm.prm file:

GrowParm.prm

Model, File, lifeform, Q10Leaf, RespLeaf10, Q10FRoot, RespFRoot10, Q10SapWood, RespSapwood10, Q10Branch, RespBranch10, Q10CRoot, RespCRoot10, InitialLeafMass, CanIntCst, BoleGrowthEffic

```
ML02 4   Herb  2.000 0.500 2.000 0.500 2.000 0.000 2.000 0.000 2.000 0.000 0.01 0.006  0.00
ML02 4   Shrub 2.000 0.500 2.000 0.500 2.000 0.050 2.000 0.050 2.000 0.050 0.01 0.006  0.50
ML02 4   Tree  2.000 0.250 2.000 0.500 2.000 0.017 2.000 0.017 2.000 0.017 0.01 0.006  1.00
```

Mort.prm

This file describes the maximum rates of mortality and branch pruning for woody layers of living plants, the time that a tree species needs to have its crown reach cell size, and the lifespan of the trees.

The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 5 indicates this is the Mort.prm file.

Species: the species or understory layer that the parameters describe. Species abbreviations are after Garrison and can be in any order.

MortMax: mortality rate of a tree species when the maximum amount of light is absorbed ($year^{-1}$).

BranchPruneMax: pruning rate of branches of a tree species when the maximum amount of light is absorbed ($year^{-1}$).

CRootPruneMax: pruning rate of coarse roots of a tree species when the maximum amount of light is absorbed ($year^{-1}$).

TimeClose: the time required for the tree species to have is crown area equal the cell area (years).

AgeMax: the maximum age of the tree species (years).

FoliageTurnoverRate: turnover rate of leaves for a species or understory layer ($year^{-1}$).

FineRootTurnover Rate: fine root turnover rate for a species or understory layer ($year^{-1}$).

Example Mort.prm file:

Mort.prm

Model, File, Species, MortMax, BranchPruneMax, CRootPruneMax,
TimeClose, AgeMax, LeafTurnoverRate, FineRootTurnoverRate

```
ML02 5 Herb    0.000 0.000  0.000    0     0  1.000  0.500
ML02 5 Shrub   0.010 0.020  0.010    0     0  0.500  0.500
ML02 5 Abam    0.007 0.020  0.005  100   500  0.200  0.500
ML02 5 Abco    0.005 0.020  0.005  100   500  0.200  0.500
ML02 5 Abgr    0.005 0.020  0.005  100   500  0.200  0.500
ML02 5 Abla    0.007 0.020  0.005  100   200  0.200  0.500
ML02 5 Abpr    0.005 0.020  0.005  100   500  0.200  0.500
ML02 5 Abma    0.005 0.020  0.005  100   500  0.200  0.500
ML02 5 Acma    0.009 0.020  0.005  100   200  1.000  0.500
ML02 5 Alru    0.009 0.020  0.005   50   120  1.000  0.500
ML02 5 Arme    0.009 0.020  0.005   50   150  0.333  0.500
ML02 5 Cach    0.009 0.020  0.005   50   150  0.333  0.500
ML02 5 Cade    0.005 0.020  0.005  100   900  0.200  0.500
ML02 5 Lide    0.009 0.020  0.005   50   150  0.333  0.500
ML02 5 Pico    0.007 0.020  0.005  100   400  0.333  0.500
ML02 5 Pila    0.005 0.020  0.005  100   500  0.333  0.500
ML02 5 Pimo    0.005 0.020  0.005  100   500  0.333  0.500
ML02 5 Pipo    0.005 0.020  0.005  100   600  0.333  0.500
ML02 5 Pien    0.005 0.020  0.005  150   500  0.200  0.500
ML02 5 Pisi    0.005 0.020  0.005  100   600  0.250  0.500
ML02 5 Potr    0.009 0.020  0.005   75   150  1.000  0.500
ML02 5 Prem    0.010 0.020  0.005   50   100  1.000  0.500
ML02 5 Psme    0.005 0.020  0.005  100  1000  0.200  0.500
ML02 5 Quga    0.005 0.020  0.005  100   300  1.000  0.500
ML02 5 Sese    0.002 0.020  0.005  100  2000  0.200  0.500
ML02 5 Thpl    0.005 0.020  0.005  100  1000  0.200  0.500
ML02 5 Tshe    0.005 0.020  0.005  100   400  0.250  0.500
ML02 5 Tsme    0.005 0.020  0.005  100   400  0.200  0.500
```

Decomp.prm

This file defines the decomposition rates of all the detrital pools except StableSoil. The decomposition rate of StableSoil is defined in the DcayParm.prm file.

All the parameters are specific to a species of tree or to the shrub or herb layers that are producing detritus. The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 6 indicates this is the Decomp.prm file.

Species: the species or understory layer that the parameters describe. Species abbreviations are after Garrison and can be in any order.

FoliageDecayRate: foliage decay rate based upon leaf lignin/nitrogen ratio at 10 C and no moisture limitations (year^{-1}).

FineRootDecayRate: fine root decay rate based upon the lignin/nitrogen ratio of the layers at 10 C and optimum moisture conditions for a species or understory layer (year^{-1}).

CoarseRootDecayRate: coarse root decay rate for a species or understory layer at 10 C and optimum moisture conditions (year^{-1}).

SapWoodDecayRate: sapwood decay rate of a species at 10 C and moisture optimum for a species or understory layer (year^{-1}).

HeartWoodDecayRate: heartwood decay rate of a species at 10 C and moisture optimum (year $^{-1}$).

BranchDecayRate: decay rate of dead branches at 10 C and optimum moisture conditions (year^{-1}).

Example Decomp.prm file:

Decomp.prm

Model, File, Species, Leaf, FineRoot, CoarseRoots,
Sapwood, Heartwood, Branch

```
ML02 6 Herb  0.500 0.500  0.000 0.000 0.000 0.000
ML02 6 Shrub 0.250 0.250  0.100 0.050 0.000 0.100
ML02 6 Abam  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Abco  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Abgr  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Abla  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Abpr  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Abma  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Acma  0.250 0.150  0.150 0.050 0.050 0.150
ML02 6 Alru  0.250 0.150  0.150 0.050 0.050 0.150
ML02 6 Arme  0.250 0.150  0.100 0.050 0.010 0.100
ML02 6 Cach  0.250 0.150  0.100 0.050 0.010 0.100
ML02 6 Cade  0.150 0.150  0.100 0.050 0.005 0.100
ML02 6 Lide  0.250 0.150  0.100 0.050 0.010 0.100
ML02 6 Pico  0.150 0.150  0.100 0.050 0.020 0.100
ML02 6 Pila  0.150 0.150  0.100 0.050 0.020 0.100
ML02 6 Pimo  0.150 0.150  0.100 0.050 0.020 0.100
ML02 6 Pipo  0.150 0.150  0.100 0.050 0.020 0.100
ML02 6 Pien  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Pisi  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Potr  0.250 0.150  0.100 0.050 0.050 0.100
ML02 6 Prem  0.250 0.150  0.100 0.050 0.005 0.100
ML02 6 Psme  0.150 0.150  0.100 0.050 0.015 0.100
ML02 6 Quga  0.250 0.150  0.100 0.100 0.050 0.010
ML02 6 Sese  0.150 0.150  0.100 0.050 0.005 0.100
ML02 6 Thpl  0.150 0.150  0.100 0.050 0.005 0.100
ML02 6 Tshe  0.150 0.150  0.100 0.050 0.050 0.100
ML02 6 Tsme  0.150 0.150  0.100 0.050 0.050 0.100
```

DcayParm.prm

This file defines the response of each detrital layer (e.g., dead foliage) to moisture and temperature (Q10's and moisture limits) and also has the transfer rates to the stable soil organic matter pool.

The parameters in the order they occur in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 7 indicates this is the DcayParm.prm file.

Pool: detrital pool the parameter values describe. Valid names include: DeadFoliage, DeadFineRoot, DeadSapWood, DeadHeartWood, DeadBranch, DeadCRoot, and StableSoil.

Q10: rate at which the decomposition rate for a pool increases with a 10 C increase in temperature (dimensionless).

TempOpt: temperature optimum for decay (C).

MoistMin: moisture minimum for decay (% water weight to dry weight for all pools except StableSoil which is in volume of water to volume of soil).

MoistMax: moisture maximum for decay (% water weight to dry weight for all pools except StableSoil which is in volume of water to volume of soil).

SoilTransferRate: transfer rate to StableSoil from the detrital pool (year^{-1}).

SoilDecayRate: rate at which StableSoil decomposes (year^{-1}) Note this parameter is zero except for StableSoil.

Drying Constant: rate at which a pool dries at temperature of 1 C and solar input of 1 cal cm^{-2} month^{-1} (cm^2 degrees^{-1} cal^{-1}).

AreaMassRatio: ratio of projected area to mass of a pool (% area Mg mass^{-1}).

MoistStoreMax: the maximum moisture content that a pool can store before becoming completely saturated (% water weight to dry weight for all pools except StableSoil which is in volume of water to volume of soil).

MatricShape: parameter that determines the shape of the matric limitation (i.e,. when detritus is too dry) curve (dimensionless).

MatricLag: parameter that determines the difference between the minimum moisture content and the response to excessive drying (%).

DiffuseShape: parameter that determines the shape of the diffusion limitation curve (dimensionless).

DiffuseLag: parameter that determines the difference between the maximum moisture content and the decline in the diffusion limitation curve (%).

TempShape: parameter that determines the shape of the excessive temperature limitation curve (dimensionless).

TempLag: parameter that determines the difference between the maximum temperature and the decline due to excessive temperature (C).

Example DcayParm.prm file:

DcayParm.prm

Model, File, Pool, Q10, TempOpt, MoistMin, MoistMax, SoilTransferRate, SoilDecayRate , DryingConstant, AreaMassRatio, MoistStoreMax, MatricShape, MatricLag, DiffuseShape, DiffuseLag, TempShape, TempLag

```
ML02 7 DeadFoliage   2.000  45  30  350  0.001 0.0000 0.00150 20.0000  300  5.0  0 15  4 15 4
ML02 7 DeadFineRoot  2.000  45  30  300  0.020 0.0000 0.00000  0.0000  300  5.0  0 15  4 15 4
ML02 7 DeadSapWood   2.000  45  30  150  0.000 0.0000 0.00075  0.1000  300  5.0  0 15  4 15 4
ML02 7 DeadHeartWood 2.000  45  30  150  0.000 0.0000 0.00025  0.0500  200  5.0  0 15  4 15 4
ML02 7 DeadBranch    2.000  45  30  200  0.000 0.0000 0.00150  0.1000  200  5.0  0 15  4 15 4
ML02 7 DeadCRoot     2.000  45  30  150  0.020 0.0000 0.00000  0.0000  200  5.0  0 15  4 15 4
ML02 7 StableSoil    2.000  45  15  100  0.000 0.0010 0.00000  0.0000  100  5.0  0 15  4 15 4
```

BurnKill.prm

This file describes the fraction of the live layers that is killed given a fire of certain serverity. The parameters occur in the following order:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 8 indicates this is the BurnKill.prm file.

Layer: refers to the layer of living vegetation. Valid names include herb, shrub, utree, and ltree.

Fire: type of fire occuring. Valid names include Hot, Medium, and Light.

AboveKill: proportion of above-ground parts (foliage, branches, sapwood, and heartwood) killed by the fire (%).

BelowKill: proportion of below-ground parts (fine roots and coarse roots) killed by the fire (%).

AboveBurn: proportion of the above-ground parts that are killed by fire that are combusted (%).

BelowBurn: proportion of the below-ground parts that are killed by fire that are combusted (%).

Example Burnkill.prm file:

BurnKill.prm

Model, File, Layer, Fire, AbvKill, BlwKill, AboveBurn, BelowBurn

```
ML02    8  Herb    Hot       99.95  100  100  100
ML02    8  Shrub   Hot       99.95  100   95    0
ML02    8  LTree   Hot      100.00  100    5    0
ML02    8  UTree   Hot      100.00  100    0    0
ML02    8  Herb    Light     99.95  100  100    0
ML02    8  Shrub   Light     50.00.  50   50    0
ML02    8  LTree   Light     80.00   80    0    0
ML02    8  UTree   Light     10.00   10    0    0
ML02    8  Herb    Medium   99.95  100  100    0
ML02    8  Shrub   Medium   50.00   50   50    0
ML02    8  LTree   Medium   80.00   80    0    0
ML02    8  UTree   Medium   10.00   10    0    0
```

SitePrep.prm

This file describes the amount of detritus removed by various types of fires. The parameters occur in the following order:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 9 indicates this is the SitePrep.prm file.

Pool: refers to the pool of detritus. Valid names include: DeadFoliage, DeadFineRoot, DeadSapWood, DeadHeartWood, DeadBranch, DeadCRoot, and StableSoil.

LightBurn: amount remaining after a light intensity fire (percent).

MediumBurn: amount remaining after a medium intensity fire (percent).

HotBurn: amount remaining after a hot intensity fire (percent).

Example of SitePrep.prm file:

Siteprep.prm

Model, File, Pool, LightBurn, MediumBurn, HotBurn

```
ML02   9  DeadFoliage     75.0  50.0  10.0
ML02   9  DeadFineRoot  100.0  75.0  20.0
ML02   9  DeadSapWood     95.0  75.0  50.0
ML02   9  DeadHeartWood 100.0  90.0  75.0
ML02   9  DeadBranch      75.0  50.0  10.0
ML02   9  DeadCRoot      100.0 100.0  95.0
ML02   9  StableSoil     100.0 100.0 100.0
```

Harvest.prm

This file describes the amount of trees cut, the fraction of the bole removed, and the fraction left on the site as slash.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 10 indicates this is the Harvest.prm file.

Treat: harvest treatment used with **PCom** as precommercial thinning, **Com** as commercial thinning, and **CCut** as clear-cut. Note these are the treatments for the cells that are cut and do not necessarily pertain to all the cells. The abbreviations of these treatments is fixed.

LoAmtCut: the fraction of the tree boles that are cut under low utilization standards (% of volume).

LoAmtTake: the fraction of the boles that are cut that is taken under low utilization standards (% of volume).

MedAmtCut: the fraction of the tree boles that are cut under medium utilization standards (% of volume).

MedAmtTake: the fraction of the boles that are cut that is taken under medium utilization standards (% of volume).

HiAmtCut: the fraction of the tree boles that are cut under high utilization standards (% of volume).

HiAmtTake: the fraction of the boles that are cut that is taken under high utilization standards (% of volume).

Example Harvest.prm file:
Harvest.prm
Model, File, Treatment, LoAmtCut, LoAmtTake,MedAmtCut, MedAmtTake, HiAmtCut, HiAmtTake

```
ML02 10   PCom   5   0  10  0  20  0
ML02 10    Com   5  50  10 90  20 95
ML02 10   CCut  80  65  95 80 100 95
```

Soil.prm

This file contains the data for various types of soils in terms of their depth and maximum moisture holding capacity.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 11 indicates this is the Soil.prm file.

SoilTexture: indicates the soil texture. Valid names include: sand, loamysand, sandyloam, loam, siltloam, silt, sandyclayloam, clayloam, siltyclayloam, sandyclay, siltyclay, and clay.

WaterPotAsym: a pararmeter that modifies the moisture retention curve so that sandier soils will release more moisture with a smaller change in the water potential (MPa).

WaterPot1: the fraction of the water stores when the water potential is equal to 1 MPa.

SoilWaterMaxPer: the maximum fraction of the soil depth that can hold water from field capacity to the wilting point (%).

Example of Soil.prm file:
Soil.prm

Model, File, WaterPotAsym, WaterPot1, SoilWaterMaxPer

```
ML02 11   sand             0.00 0.25  25.0
ML02 11   loamysand        0.12 0.25  35.0
ML02 11   sandyloam        0.25 0.25  35.0
ML02 11   loam             0.50 0.25  45.0
ML02 11   siltloam         0.50 0.25  50.0
ML02 11   silt             0.60 0.25  50.0
ML02 11   sandyclayloam    0.65 0.25  50.0
ML02 11   clayloam         0.75 0.25  50.0
ML02 11   siltyclayloam    0.75 0.25  50.0
ML02 11   sandyclay        0.60 0.25  45.0
ML02 11   siltyclay        0.85 0.25  60.0
ML02 11   clay             1.00 0.25  60.0
```

SiteIndx.prm

This file contains the bole growth efficiencies in terms of mass of sapwood produced per unit mass of foliage for the commercial tree species growing in the Pacific Northwest. These parameters are set so that bole mass and volume accumulation matches a site index related volume table (Table 2).

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 12 indicates this is the SiteIndex.prm file.

SiteIndexSpecies: the species that is to be used to determine the level of productivity. Species abbreviations are after Garrison and can be in any order.

Site1High: the bole growth efficiency to match a high site index 1 productivity (dimensionless).

Site1Medium: the bole growth efficiency to match a medium site index 1 productivity (dimensionless).

Site1Low: the bole growth efficiency to match a low site index 1 productivity (dimensionless).

Site2High: the bole growth efficiency to match a high site index 2 productivity (dimensionless).

Site2Medium: the bole growth efficiency to match a medium site index 2 productivity (dimensionless).

Site2Low: the bole growth efficiency to match a low site index 2 productivity (dimensionless).

Site3High: the bole growth efficiency to match a high site index 3 productivity (dimensionless).

Site3Medium: the bole growth efficiency to match a medium site index 3 productivity (dimensionless).

Site3Low: the bole growth efficiency to match a low site index 2 productivity (dimensionless).

Site4High: the bole growth efficiency to match a high site index 4 productivity (dimensionless).

Site4Medium: the bole growth efficiency to match a medium site index 4 productivity (dimensionless).

Site4Low: the bole growth efficiency to match a low site index 4 productivity (dimensionless).

Site5High: the bole growth efficiency to match a high site index 5 productivity (dimensionless).

Site5Medium: the bole growth efficiency to match a medium site index 5 productivity (dimensionless).

Site5Low: the bole growth efficiency to match a low site index 5 productivity (dimensionless).

Example SiteIndx.prm file:

SiteIndx.prm

Model, File, SiteIndexSpecies, Site1High, Site1Med, Site1Low,
Site2High, Site2Med, Site2Low, Site3High, Site3Med, Site3Low,
Site4High, Site4Med, Site4Low, Site5High, Site5Med, Site5Low

```
ML02 12 Abco  1.15 1.08 1.04 1.01 0.90 0.83 0.74 0.66 0.57 0.48 0.40 0.33 0.30 0.27 0.25
ML02 12 Abgr  1.00 0.95 0.85 0.80 0.75 0.70 0.65 0.59 0.52 0.48 0.42 0.36 0.30 0.24 0.18
ML02 12 Pico  1.10 1.00 0.91 0.83 0.75 0.69 0.62 0.55 0.49 0.43 0.37 0.31 0.25 0.20 0.15
ML02 12 Pimo  0.92 0.86 0.80 0.76 0.71 0.68 0.64 0.60 0.57 0.54 0.51 0.47 0.42 0.38 0.32
ML02 12 Pipo  1.92 1.65 1.50 1.45 1.22 1.06 0.89 0.75 0.65 0.55 0.45 0.41 0.35 0.30 0.25
ML02 12 Pisi  1.70 1.60 1.52 1.44 1.35 1.27 1.13 1.00 0.92 0.84 0.75 0.65 0.56 0.48 0.40
ML02 12 Psme  1.00 0.95 0.90 0.86 0.82 0.77 0.72 0.66 0.60 0.52 0.45 0.38 0.32 0.26 0.19
ML02 12 Tshe  1.50 1.41 1.32 1.27 1.18 1.11 1.06 0.98 0.90 0.83 0.76 0.67 0.58 0.48 0.42
ML02 12 Sese  1.60 1.41 1.33 1.23 1.07 0.98 0.84 0.73 0.66 0.59 0.51 0.42 0.38 0.35 0.30
```

Table 2. Correspondence between site index classes and site index values (height in feet at 50 years of age).

	Site Class Class														
	I			II			III			IV			V		
Species	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low
Abies concolor[1]	100	90	85	80	75	70	65	60	55	50	45	40	35	30	25
Abies grandis[2]	110	105	100	95	90	85	80	75	70	65	60	55	50	45	40
Picea sitchensis[3]	132	126	118	114	108	101	95	88	82	76	69	63	57	51	45
Pinus contorta[4]	75	70	66	63	60	56	53	50	46	43	40	36	33	30	25
Pinus monticola[5]	80	75	70	65	60	56	53	50	46	43	40	36	33	30	25
Pinus pondersosa[6]	113	105	97	89	80	73	65	58	51	43	35	28	21	14	7
Pseudotsuga menziesi[7]	146	139	132	125	119	112	105	98	91	84	77	70	63	56	49
Sequoia sempervirons[8]	171	155	148	138	130	122	114	106	97	89	81	73	65	57	49
Tsuga heterophylla[9]	135	128	121	115	109	102	96	90	83	77	70	64	58	51	45

1-Schumacher 1926, 2-Cochran 1979, 3-Meyer 1937,4-Dahm 1964, 5-Haig 1932, 6-Meyer 1938. 7-McArdle and Meyer 1930, 8-Lundquist and Palley, and 9-Barnes 1962.

Driver Files

These files are also used to parameterize each simulation run. They differ, however, from the parameter files in that they are not constant but change from run to run. We therefore refer to these as driver files. The extension of these files is **DRV**. The driver files required to run the STANDCARB model are outlined in Table 3.

For each the model object needing the file is described. Next the parameters are defined and the units indicated. The format in terms of columns is flexible, however, the parameters must be listed in the order shown.

Table 3. Driver files required to run STANDCARB model and the function of each file. Note that the UNIX version is case sensitive and the files names must be ass shown below.

File Name	Function
Simul.drv	defines the characteristics of a simulation run
Locate.drv	defines the physical characteristics of site such as aspect
Climate.drv	defines the precipitation and temperature regime of site
Radiate.drv	defines the solar radiation and sun angles for a site
WFireInt.drv	defines the timing and severity of wildfires
HarvInt.drv	defines the timing and type of harvest and cutting in a stand
CutPatt.drv	defines the spatial patterns of the harvests or cuts.
WFPatt.drv	defines the spatial patterns of wildfires

Simul.drv

This file is used to define the overall nature of a simulation run. It defines the number of cells, the length of time the model is run, the time layers are planted (in the single cell version), whether diagnostic fiels are to be output, the type of output files to be output, and other aspects of the particular run.

ModelNumber: ML02 indicates this file is input for STANDCARB. This keyword is required.

InputFileNumber: 21 indicates this is the Simul.drv file. This keyword is required.

SpeciesUpper: for single cell version the tree species in the upper tree layer.

SpeciesLower: for single cell version the tree species in the lower tree layer.

SiteName: name of the site being examined in the simulations.

GrowthMethod: the method used to determine the growth rate of plants.
Valid selections include Climate or SiteIndex. If Climate is selected then the rate of growth is solved from climatic indices. If SiteIndex is used then the growth rate matches that required to mimic a volume table.

SiteIndexSpecies: the species the growth should match if the SiteIndex growth method is selected.

SiteIndex: the site index level being selected. Valid levels include: Site1High, Site1Medium, Site1Low, Site2High, Site2Medium, Site2Low, Site3High, Site3Medium, Site3Low, Site4High, Site4Medium, Site4Low, Site5High, Site5Medium, Site5Low.

Regen: the regeneration scenario to be used. Valid names include: NF (natural fast), NS (natural slow), AF (artifical fast), and AS (artificial slow).

#ofRows: the number of rows in stand.

#ofCols: the number of columns in stand.

TimeEnd: the number of years the simulation is to run (years).

Interval: the time interval that results are output (e.g., 5 years). The smallest interval is 1 year.

CellWidth: the width of the cell to be used in determining the distance between trees (m). This correspondes to the width of a mature tree.

TimeHerb: for single cell version the time the herb layer is planted.

TimeShrub: for single cell version the time the shrub layer is planted.

TimeUpper: for single cell version the time the upper tree layer is planted.

TimeLower: for single cell version the time the lower tree is planted.

Border: the type of border to be used in the Neighbor calculations. Valid names include: None, Same, and Old.

Neighbor: determines if the cells interact spatially (ON) or are independent spatially (OFF).

Restart: determines if layers can restart after disturbance in the single cell version of model. A 1 makes the layers restart after disturbance that reduces their biomass to 0. A 0 indicates the layers will not restart once their biomass is reduced to zero.

PETReduction: the amount of potential evapotranspiration that is lost via evaporation (%).

InitialSoilCarbon: an estimate of the stable soil carbon (Mg ha^{-1}). This reduces the time needed to calibrate the stable soil pool. This value will change according to the climate and productivity of the site, be sure the correct value is used!

Units: determines whether the mass values are output as organic matter or carbon . Valid codes are **OM** (organic matter) or **C** (carbon). The model assumes that all organic matter is 50% carbon.

Diagnostics Mode: a 1 indicates that only diagnostic files are to be output, a 0 indicates only output files of states variables are output, and 10 indicates both diagnostic and output files are to be output. *Note that in the present version one cannot run all the diagnostic functions at once. It is best to limit the number of diagnostic tests to less than 10.*

Plant Diagnostics: a 1 indicates that diagnostic files on the frequency of cells in layers and tree species are to be output. In this mode, the layers and species are planted, but not allowed to die out. A 0 means that this diagnostic is not run.

DieOut Diagnostics: a 1 indicates that diagnostic files on the frequency of cells in layers and tree species are to be output. In this mode, the layers are planted for 100 years and then there is no planting or replacement after that time. A 0 means that this diagnostic is not run.

Replacement Diagnostics: a 1 indicates that diagnostic files on the frequency of cells in layers and tree species are to be output. In this mode, layers and species are planted, die out, and are replaced similar to the normal simulation runs. A 0 means that this diagnostic is not run.

Interception Diagnostics: a 1 indicates the interception values for the canopy and detrital pools, and monthly runoff will be output. These are for the temperature, precipitation, soil, and radiation conditions of the site. A 0 means that this diagnostic is not run.

Water Balance Diagnostics: a 1 prints out the moisture content of the detrital pools and soil. These are for the temperature, precipitation, soil, and radiation conditions of the site. A 0 means that this diagnostic is not run.

Transpiration Diagnostics: a 1 prints out the potential transpiration and the actual transpiration. These are for the temperature, precipitation, soil, and radiation conditions of the site. A 0 means that this diagnostic is not run.

Temperature Response Diagnostics: a 1 indicates that the response of growth, plant respiration, and decomposition to temperature is to be output. In this mode a systematic progression of temperature values is used (0-50 C by 1 C increments) rather than the values in the Climate.drv file. A 0 means that this diagnostic is not run.

Detrital Moisture Response Diagnostics: a 1 indicates that the response of decomposition to moisture is to be output. In this mode a systematic progression of moisture values is used (0-500 % by 5 % increments) rather than the values computed from the WaterBalance functions. A 0 means that this diagnostic is not run.

Abiotic Response Diagnostics: a 1 indicates that the combined response of growth and decomposition to temperature and moisture is to be output. These are for the temperature, precipitation, soil, and radiation conditions of the site. A 0 means that this diagnostic is not run.

Light Diagnostics: a 1 indicates that the mean light entering and leaving a stand will be printed out for each time step. A 0 means that this diagnostic is not run.

Respiration Diagnostics: a 1 indicates that the losses from respiration and the mass of the respiring pools is to be output. 0 means that this diagnostic is not run.

Mortality Diagnostics: a 1 indicates the mass of mortality from all sources (pruning, mortality, thinning, dieout, fire) is to be output. A 0 means that this diagnostic is not run.

Substrate Quality Diagnostics: a 1 indicates that the portion of the decomposition rate of each pool that is dependent on substrate quality (PoolDecayRateAvg) is printed out. A 0 means that this diagnostic is not run.

Water Potential Diagnostics: a 1 indicates that the response of water potential and growth to soil water stores will be output. A 0 means that this diagnostic is not run.

Neighbor Diagnostics: a 1 indicates that the fraction of full diffuse, direct, and total radiation will be printed out for a selected year. A 0 means that this diagnostic is not run.

Year Neighbor: indicates the year that the Neighbor Diagnostic is to be performed.

RandomNum: a random number used to seed the random number generator. This should be a negative integer between -1 and -65,536.

Example Simul.drv file

```
ModelNumber          ML02
InputFileNumber     21
SpeciesUpper        PSME
SpeciesLower        TSHE
SiteName            default
GrowthMethod        SiteIndex
SiteIndexSpecies    Psme
SiteIndex           Site2Medium
Regen               AF
#ofRows             10
#ofCols             10
TimeEnd            500
Interval             5
CellWidth           20
TimeHerb             1
TimeShrub            3
TimeUpper            5
TimeLower           50
Border              Old
NeighbourRoutine    Off
Restart              1
PETReduction         10
InitialSoilCarbon    300
Units                OM
DiagnosticsMode      0
PlantDiag            0
DieOutDiag           0
ReplacementDiag      0
InterceptionDiag     0
WaterBalanceDiag     0
TranspirationDiag    0
TempResponseDiag     0
DetritalMoistureDiag 0
AbioticResponseDiag  0
LightDiag            0
RespirationDiag      0
MortalityDiag        0
SubstrateQualityDiag 0
WaterPotnetialDiag   0
NeighborDiag         0
YearNeighbor       250
RandomNums       -320
```

Locate.drv

This file defines the location and site characteristics of the forest to be simulated.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 22 indicates this is the Locat.drv file.

SiteName: the name of the particular site being simulated.

SoilText: the soil texture class of the site. The valid names of textures are: sand, loamysand, sandyloam, loam, siltloam, silt, sandyclayloam, clayloam, siltyclayloam, sandyclay, siltyclay, and clay.

Ecoregion: the ecoregion that the site occurs in. This determines the species of trees that will be present. The valid names of ecoregions are:

California Coast Range (CACR)
California Cascades-west side (CACW)
Oregon Cascades-west slope (ORCW)
Oregon Cascades-east slope (ORCE)
Oregon Coast Range (ORCR)
Washington Cascades-west slope (WACW)
Washington Cascades-east slope (WACE)
Other (OTHR)

Latitude: the latitude of the site to the nearest degree (degree).

Elevation: the elevation above mean sea level of the site (meters).

Aspect: the compass direction that the site is sloping toward (degrees).

SlopeSteep: the steepness of the site in percent slope (%).

SoilDepth: the depth of the soil for rooting of plants (cm).

Rocks: the percentage of the soil profile that has fragments of rock >2mm in diameter (%).

Example Locat.drv file:

Locate.drv

Model, File, SiteName, SoilText, Ecoregion,
Latitude, Elevation, Aspect, SlopeSteep, SoilDepth, Rocks

```
ML02  22  defaultsite  loam   CACR  40   300  180   0  100   5
ML02  22  testsite1    loam   ORCW  44   100  180   0  100   5
ML02  22  testsite2    loam   ORCW  44  1000  180   0  100   5
ML02  22  testsite3    loam   ORCW  44  3000  180   0  100   5
```

Climate.drv

This driver file contains the climatic information required to calculate the effects of climate on establishment, growth, and decomposition.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 23 indicates this is the Climate.drv file.

Month: the month of the year staring with January and ending with December

TempMin: the mean monthly minimum temperature (C).

TempMax: the mean monthly maximum temperature (C).

Temp24: the mean monthly temperature for the entire 24 hour day (C).

Prec: the mean monthly total precipitation (cm).

Example Climate.drv file:

Climate.drv

Model, File, Month, TempMin, TempMax, Temp, Precip

```
ML02 23 Jan  -1.50  3.20  0.3  39.0
ML02 23 Feb  -0.20  7.00  2.7  27.0
ML02 23 Mar   0.10  9.40  3.8  27.0
ML02 23 Apr   1.70 14.60  7.40 14.0
ML02 23 May   4.40 19.30 11.70 11.0
ML02 23 Jun   7.30 23.30 14.9   6.0
ML02 23 Jul   9.00 28.70 18.30  1.0
ML02 23 Aug   8.60 28.00 17.4   4.0
ML02 23 Sep   6.30 24.10 13.5   8.0
ML02 23 Oct   3.40 15.80  8.10 18.0
ML02 23 Nov   0.70  7.50  3.5  34.0
ML02 23 Dec  -0.90  3.60  1.1  41.0
```

Radiate.drv

This driver file contains the radiation and sun angle information required to calculate the effects of radiation on establishment, growth, and decomposition. These data can be calculated using the SolarRad (Harmon and Marks 1995) or a similar type of program.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 24 indicates this is the Radiate.drv file.

Month: the month of the year starting with January and ending with December. Also there is a name Year which indicates the daily mean during the year for radiation and the yearly weighted average for the sun angles.

DifSolRad: mean daily diffuse solar radiation for a given site (cal cm^{-2} day^{-1}). To calculate the monthly radiation multiply this number by the number of days in the month. For the year, this is the daily mean for the year. To calculate the yearly radiation multiply the year value by 365.

DirSolRad: mean daily direct solar radiation for a given site (cal cm^{-2} day^{-1}). To calculate the monthly radiation multiply this number by the number of days in the month. For the year, this is the daily mean for the year. To calculate the yearly radiation multiply the year value by 365.

SolRad: mean daily total solar radiation for a given site (cal cm^{-2} day^{-1}). To calculate the monthly radiation multiply this number by the number of days in the month. For the year, this is the daily mean for the year. To calculate the yearly radiation multiply the year value by 365.

SunriseAzimAngle: the azimuth angle of the sun at sunrise for each month (degrees from south). The year value is the weighted average, weighted by total radiation received each month.

SolarAltAngleSouth: solar altitude angle when the sun is directly south (degrees from the horizon) The year value is the weighted average, weighted by total radiation received each month.

Example of the Radiate.drv file:

Radiate.drv

Model, File, Month, DifSolRad, DirSolarRad, SolRad
SunriseAzimuthAngle, AltAngleSouth

```
ML04 24  Jan   75.63   30.13  105.76   68.34   25.08
ML04 24  Feb  110.80   57.34  168.14   77.17   33.04
ML04 24  Mar  156.03   89.96  245.99   87.67   43.58
ML04 24  Apr  203.91   47.37  351.28   99.22   55.42
ML04 24  May  236.78   99.01  435.79  109.19   64.79
ML04 24  Jun  240.49  272.79  513.28  114.32   69.09
ML04 24  Jul  156.07  515.59  671.66  111.99   67.18
ML04 24  Aug  196.07  271.42  467.49  103.37   59.46
ML04 24  Sep  169.66  152.64  322.30   92.15   48.22
ML04 24  Oct  124.37   75.85  200.22   80.61   36.40
ML04 24  Nov   84.10   36.94  121.04   70.68   27.09
ML04 24  Dec   66.28   24.46   90.74   65.74   22.95
ML04 24 Year  151.68  156.13  307.81   99.30   55.01
```

WFireInt.drv

This driver file describes the time and severity of wildfires that burn through the stand. This file allows one to specify if the fires are light, medium or hot. The severity of the fire effects the amount of live layers killed and the amount of detritus burned away. The years indicate when various fires occur. To have more than one fire of a type occur use another line. If one fire type is invoked more than another, put a zero in the treaments that are not used.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 25 indicates this is the WFireInt.drv file.

LIGHTFIRE: year that a light fire occurs (year).

MEDIUMFIRE: year that a medium fire occurs (year).

HOTFIRE: year that a hot fire occurs (year).

Example WfireInt.drv file with light fires in years 50, 100, and 150 and a hot fire in year 250:

WFireInt.drv

Model, File, LiteFire, MedFire, HotFire

```
ML02 25    50   0  250
ML02 25   100   0    0
ML02 25   150   0    0
```

HarvInt.drv

This file describes the intervals and tree layers that are harvested, the type of harvest, the degree of utilization, and the type of site preparation that is used. For each harvest step or action there are four variables to describe the action taken. The year a layer (i.e., upper or low tree) is harvested, the type of utilization standard used (amount of bole removed), and the type of site preparation fire used. The years indicate when various actions are taken. To have a treatment occur more than once use another line. If one harvest treatment is invoked more than another, put a zero in the treatments that are not used. Also if fire is not used then use a zero to indicate no fire.

The variables in the order of their appearance in the file are as follows:

Model Number: ML02 indicates this file is input for STANDCARB.

Input File Number: 26 indicates this is the HarvInt.drv file.

PComIntUT: time of precommercial thinning of the upper tree layer (years).

PComIntLT: time of precommercial thinning of the lower tree layer (years).

PComUtilization: the utilization standards used in the precommercial thinning (see the Harvest.drv file to define levels). For the utilization standards the valid codes for levels are: 1-low utilization, 2-medium utilization,and 3-high utilization.

PComFireType: the type of fire used after a precommercial thinning. For site preparation fires the valid codes for the type of fire are: 0-no fire, 1-light fire, 2-medium fire, and 3-hot fire.

ComIntUT: time of commercial thinning of the upper tree layer (years).

ComIntLT: time of commercial thinning of the lower tree layer (years).

ComUtilization: the utilization standards used in the commercial thinning (see the Harvest.drv file to define levels). For the utilization standards the valid codes for levels are: 1-low utilization, 2-medium utilization,and 3-high utilization.

ComFireType: the type of fire used after a commercial thinning. For site preparation fires the valid codes for the type of fire are: 0-no fire, 1-light fire, 2-medium fire, and 3-hot fire.

CCutIntUT: time of clear-cutting the upper tree layer (years).

CcutIntLT: time of clear-cutting of the lower tree layer (years).

CCutUtilization: the utilization standards used in the clear-cut harvest (see the Harvest.drv file to define levels). For the utilization standards the valid codes for levels are: 1-low utilization, 2-medium utilization,and 3-high utilization.

CCutFireType: the type of fire used after a clear-cut harvest. For site preparation fires the valid codes for the type of fire are: 0-no fire, -light fire, 2-medium fire, and 3-hot fire.

Example of HarvInt.drv file with clearcutting in years 200, and 310, and precommercial thinning in years 240, 260, 280, and 300. All harvests are high utilization standards with no site preparation fires:

HarvInt.drv

Model, File, PComIntUT, PComIntLT, PComUtilization, PComFireType,
ComIntUT, ComIntLT, ComUtilization, ComFireType,
CCutIntUT, CCutIntLT, CCutUtilization, CCutFireType

```
ML02 26    0    0 0 0 240   240 3 0 200   200 3 3
ML02 26    0    0 0 0 260   260 3 0 310   310 3 3
ML02 26    0    0 0 0 280   280 3 0   0     0 0 0
ML02 26    0    0 0 0 300   300 3 0   0     0 0 0
```

CutPatt.drv

This file describes the cutting patten of the cells and takes the form of a row by column pattern to indicate the pattern of cells that are thinned or clear-cut. The lowest row number corresponds to the uppermost (uphill) portion of the stand and the lowest column number corresponds to the lefthand side of the stand as one "looks" uphill. If a cell has a value of 1 it is to have the treatment, if the cell has a value of 0 it does not recieve the treatment. The year a pattern is imposed is indicated in the line with year on it; a pattern may be used for more than one year. Years should be separated by commas. *Note that the number of rows and columns indicated in the Simul.drv file must match the number of rows and columns in the CutPatt.drv file!*

Example CuttPatt.drv file for a 10 X 10 cell stand with clearcuts in an alternating checker board at 50, 100, 150, and 200 years.

```
ML02  27
Year 50, 150
1  1  0  0  1  1  0  0  1  1
1  1  0  0  1  1  0  0  1  1
0  0  1  1  0  0  1  1  0  0
0  0  1  1  0  0  1  1  0  0
1  1  0  0  1  1  0  0  1  1
1  1  0  0  1  1  0  0  1  1
0  0  1  1  0  0  1  1  0  0
0  0  1  1  0  0  1  1  0  0
1  1  0  0  1  1  0  0  1  1
1  1  0  0  1  1  0  0  0  0
downhill

Year 100, 200
0  0  1  1  0  0  1  1  0  0
0  0  1  1  0  0  1  1  0  0
1  1  0  0  1  1  0  0  1  1
1  1  0  0  1  1  0  0  1  1
0  0  1  1  0  0  1  1  0  0
0  0  1  1  0  0  1  1  0  0
1  1  0  0  1  1  0  0  1  1
1  1  0  0  1  1  0  0  1  1
0  0  1  1  0  0  1  1  0  0
0  0  1  1  0  0  1  1  0  0
downhill
```

WFPatt.drv

This file describes the burn patten of the cells and takes the form of a row by column pattern to indicate the pattern of cells that are burned by a wildfire. The lowest row number corresponds to the uppermost (uphill) portion of the stand and the lowest column number corresponds to the lefthand side of the stand as one "looks" uphill. If a cell has a value of 1 it is burned, if the cell has a value of 0 it does not burn. The year a pattern is imposed is indicated in the line with year on it; a pattern may be used for more than one year. Years should be separated by commas. *Note that the number of rows and columns indicated in the Simul.drv file must match the number of rows and columns in the CutPatt.drv file!*

Example WFPatt.drv file for a 10 X 10 cell stand with partial burns years 50 and 100, followed by a complete burn at 150 years.

```
ML02  27
Year 50
1  1  1  1  1  1  0  0  0  0
1  1  1  1  1  1  0  0  0  0
1  1  1  1  1  1  1  1  0  0
1  1  1  1  1  0  1  1  0  0
1  1  1  1  1  1  0  0  0  0
1  1  0  0  1  1  0  0  0  0
0  0  1  1  0  0  1  1  0  0
0  0  0  0  0  0  0  0  0  0
1  1  0  0  0  0  0  0  0  0
1  1  0  0  0  0  0  0  0  0
downhill

Year 100
0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  1  1  0  0
0  0  0  0  1  1  1  1  1  1
0  0  0  0  1  1  1  1  1  1
0  0  1  1  1  1  1  1  1  1
0  0  1  1  1  1  1  1  1  1
0  0  0  0  1  1  1  1  1  1
0  0  0  0  1  1  0  0  1  1
0  0  0  1  0  0  1  1  0  0
0  0  0  0  0  0  1  1  0  0
downhill

Year 150
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
1  1  1  1  1  1  1  1  1  1
downhill
```

Output Files

These files represent the standard output files that each model simulation generates. All output files have the extension OUT. Each file is composed of two parts: 1) a header section that describes the format of the data and 2) the output data itself.

The output file format in terms of columns is flexible, however, the parameters must be listed in the order shown. An example of each file is given.

Table 4. List of output files currently available for the STANDCARB model.

File Name	Purpose
Total.out	total organic matter or carbon values for live and dead pools
Live.out	total organic matter or carbon values for live pools
Dead.out	total organic matter or carbon values for dead pools
Volume.out	volume, age, and height of tree layers

Total.out

This file has the totals of the organic matter or carbon stores and the volume harvested. This is the most commonly used output file for assessing overall effects of treatments on stores of organic matter or carbon. When the single cell version of the model is used only the mean stores are output and the standard error is set to zero. When the multicell version is used then the mean and the standard error are output.

The variables defined in the order they appear in the file are:

Model Number: ML02 indicates this file is output for STANDCARB.

Output File Number: 31 indicates this is the Total.out file.

Time: simulation year. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variables will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs then the effects of this disturbance will be calculated and output for time Year.04. This allows one to directly track that changes in stores for each disturbance in a given year.

TotalLiveMean: mean of the total live carbon for all the cells (Mg ha^{-1}). Includes boles, branches, leaves, fine roots, and coarse roots for herbs, shrubs, upper trees ,and lower trees.

TotalLiveSte: standard error of the total live carbon for all the cells (Mg ha^{-1}). Includes all live forms as above.

TotalDeadMean: mean of the total dead carbon for all the cells (Mg ha^{-1}). Includes dead foliage, dead fine roots, dead coarse roots, dead branches, dead sapwood, dead heartwood, and stable soil.

TotalDeadSte: standard error of the total dead carbon for all the cells (Mg ha^{-1}). Includes all the dead pools described above.

LabileDeadMean: mean of the total dead carbon for all the cells except for the stable soil (Mg ha^{-1}). Includes dead foliage, dead fine roots, dead coarse roots, dead branches, dead sapwood, and dead heartwood. This is the fraction of dead material that is expected to change significantly with varying silvicultural treatment.

LabileDeadSte: standard error of the total dead carbon for all the cells except for the stable soil (Mg ha^{-1}). Includes all the dead pools described above.

Volume: the mean cubic volume, excluding bark, of upper and lower trees (cubic meters ha^{-1}).

Harvest: the mean harvested volume made during each year. Thisis for bole volume excluding bark (cubic meters ha^{-1}).

Example Total.out file (note the first lines are a header that appears with each output file, listing variables in the order they appear in columns):

ModelNum, FileNum, Time, TotalLiveMean, TotalLiveSte, TotalDeadMean,
TotalDeadSte, LabileDeadMean, LabileDeadSte, Volume, Harvest

```
ML02  31    1.0      0.04    0.00   302.24    0.00     0.01    0.00     0.00    0.00
ML02  31    2.0      0.15    0.00   300.56    0.00     0.05    0.00     0.00    0.00
ML02  31    3.0      0.50    0.00   298.96    0.00     0.16    0.00     0.02    0.00
ML02  31    4.0      1.49    0.00   297.62    0.00     0.52    0.00     0.05    0.00
ML02  31    5.0      4.29    0.00   296.97    0.00     1.56    0.00     0.09    0.00
ML02  31    6.0     11.07    0.00   298.26    0.00     4.56    0.00     0.16    0.00
ML02  31    7.0     19.04    0.00   304.44    0.00    12.61    0.00     0.25    0.00
ML02  31    8.0     22.01    0.00   314.17    0.00    24.38    0.00     0.40    0.00
ML02  31    9.0     23.17    0.00   319.80    0.00    32.03    0.00     0.62    0.00
ML02  31   10.0     23.98    0.00   324.06    0.00    38.26    0.00     0.94    0.00
.......................................................................................
ML02  31   20.0     69.40    0.00   322.61    0.00    55.74    0.00    42.10    0.00
ML02  31   21.0     89.47    0.00   313.12    0.00    47.82    0.00    54.49    0.00
ML02  31   22.0    100.06    0.00   319.49    0.00    55.85    0.00    68.12    0.00
ML02  31   23.0    118.91    0.00   312.66    0.00    50.54    0.00    82.63    0.00
........................................................................................
ML02  31   45.0    489.53    0.00   367.45    0.00   127.12    0.00   450.18    0.00
ML02  31   46.0    503.96    0.00   370.47    0.00   130.67    0.00   465.42    0.00
ML02  31   47.0    517.99    0.00   373.60    0.00   134.29    0.00   480.37    0.00
ML02  31   48.0    531.64    0.00   376.78    0.00   137.94    0.00   495.05    0.00
ML02  31   49.0    544.93    0.00   380.01    0.00   141.61    0.00   509.46    0.00
ML02  31   50.0    557.87    0.00   383.26    0.00   145.28    0.00   523.61    0.00
```

Live.out

This output file contains the organic matter or carbon stores for all the live components of the vegetation. When the single cell version of the model is used only the mean stores are output and the standard error is set to zero. When the multicell version is used then the mean and the standard error are output.

The variables defined in the order they appear in the file are:

Model Number: ML02 indicates this file is output for STANDCARB.

Output File Number: 32 indicates this is the Live.out file.

Time: simulation year. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variables will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs then the effects of this disturbance will be calculated and output for time Year.04. This allows one to directly track that changes in stores for each disturbance in a given year.

FoliageMean: mean of the total foliage organic matter or carbon for all the cells (Mg ha^{-1}).

FoliageSte: standard error of the total foliage organic matter or carbon for all the cells (Mg ha^{-1}).

FineRootMean: mean of the total fine root organic matter or carbon for all the cells (Mg ha^{-1}).

FineRootSte: standard error of the total fine root organic matter or carbon for all the cells (Mg ha^{-1}).

BranchMean: mean of the total branch organic matter or carbon for all the cells (Mg ha^{-1}).

BranchSte: standard error of the total branch organic matter or carbon for all the cells (Mg ha^{-1}).

SapwoodMean: mean of the total sapwood organic matter or carbon for all the cells (Mg ha^{-1}).

SapwoodSte: standard error of the sapwood organic matter or carbon for all the cells (Mg ha^{-1}).

HeartwoodMean: mean of the total heartwood organic matter or carbon for all the cells (Mg ha^{-1}).

HeartwoodSte: standard error of the heartwood organic matter or carbon for all the cells (Mg ha^{-1}).

CRootMean: mean of the total coarse root organic matter or carbon for all the cells (Mg ha^{-1}).

CRootSte: standard error of the total coarse root organic matter or carbon for all the cells (Mg ha^{-1}).

Example of Live.out file (note the first lines are a header that appears with each output file, listing variables in the order they appear in columns):

ModelNum, FileNum, Time, FoliageMean, FoliageSte, FineRootMean, FineRootSte, BranchMean, BranchSte, SapwoodMean, SapwoodSte, HeartwoodMean, HeartwoodSte, CRootMean, CRootSte

```
ML02 21   1.0      0.030     0.000     0.015     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
ML02 21   2.0      0.090     0.000     0.060     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
ML02 21   3.0      0.285     0.000     0.200     0.000     0.002     0.000     0.010     0.000     0.000     0.000     0.008     0.000
ML02 21   4.0      0.830     0.000     0.611     0.000     0.006     0.000     0.024     0.000     0.001     0.000     0.019     0.000
ML02 21   5.0      2.405     0.000     1.795     0.000     0.012     0.000     0.044     0.000     0.002     0.000     0.036     0.000
ML02 21   6.0      6.235     0.000     4.672     0.000     0.020     0.000     0.074     0.000     0.005     0.000     0.061     0.000
ML02 21   7.0     10.730     0.000     8.049     0.000     0.032     0.000     0.118     0.000     0.009     0.000     0.099     0.000
ML02 21   8.0     12.340     0.000     9.266     0.000     0.050     0.000     0.184     0.000     0.016     0.000     0.155     0.000
ML02 21   9.0     12.870     0.000     9.677     0.000     0.078     0.000     0.281     0.000     0.027     0.000     0.239     0.000
ML02 21  10.0     13.105     0.000     9.865     0.000     0.140     0.000     0.442     0.000     0.043     0.000     0.388     0.000
...........................................................................................................................
ML02 21  37.0     19.889     0.000    19.869     0.000    43.113     0.000   101.717     0.000    56.361     0.000   116.582     0.000
ML02 21  38.0     19.957     0.000    19.937     0.000    46.225     0.000   105.876     0.000    61.235     0.000   122.682     0.000
ML02 21  39.0     19.976     0.000    19.956     0.000    49.192     0.000   109.727     0.000    66.218     0.000   128.594     0.000
ML02 21  40.0     19.979     0.000    19.959     0.000    52.015     0.000   113.287     0.000    71.296     0.000   134.319     0.000
ML02 21  41.0     19.979     0.000    19.959     0.000    54.701     0.000   116.575     0.000    76.454     0.000   139.860     0.000
ML02 21  42.0     19.977     0.000    19.957     0.000    57.257     0.000   119.614     0.000    81.682     0.000   145.224     0.000
ML02 21  43.0     19.976     0.000    19.956     0.000    59.689     0.000   122.422     0.000    86.967     0.000   150.417     0.000
ML02 21  44.0     19.975     0.000    19.955     0.000    62.004     0.000   125.018     0.000    92.299     0.000   155.443     0.000
ML02 21  45.0     19.974     0.000    19.954     0.000    64.207     0.000   127.419     0.000    97.669     0.000   160.308     0.000
ML02 21  46.0     19.973     0.000    19.953     0.000    66.304     0.000   129.639     0.000   103.069     0.000   165.018     0.000
ML02 21  47.0     19.973     0.000    19.953     0.000    68.301     0.000   131.694     0.000   108.491     0.000   169.578     0.000
ML02 21  48.0     19.973     0.000    19.953     0.000    70.203     0.000   133.596     0.000   113.927     0.000   173.992     0.000
ML02 21  49.0     19.972     0.000    19.952     0.000    72.013     0.000   135.357     0.000   119.372     0.000   178.265     0.000
ML02 21  50.0     19.972     0.000    19.952     0.000    73.737     0.000   136.987     0.000   124.819     0.000   182.401     0.000-
```

Dead.out

This output file contains all the data for the detrital pools. When the single cell version of the model is used only the mean stores are output and the standard error is set to zero. When the multicell version is used then the mean and the standard error are output.

The variables defined in the order they appear in the file are:

Model Number: ML02 indicates this file is input for STANDCARB.

Output File Number: 33 indicates this is the Dead.out file.

Time: simulation year. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variables will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs then the effects of this disturbance will be calculated and output for time Year.04. This allows one to directly track that changes in stores for each disturbance in a given year.

DeadFoliageMean: mean of the dead foliage organic matter or carbon for all the cells (Mg ha^{-1}).

DeadFoliageSte: standard error of the dead foliage organic matter or carbon for all the cells (Mg ha^{-1}).

DeadFRootMean: mean of the dead fine root organic matter or carbon for all the cells (Mg ha^{-1}).

DeadFRootSte: standard error of the dead fine root organic matter or carbon for all the cells (Mg ha^{-1}).

DeadBranchMean: mean of the dead branch organic matter or carbon for all the cells (Mg ha^{-1}).

DeadBranchSte: standard error of the dead branch organic matter or carbon for all the cells (Mg ha^{-1}).

DeadSapwoodMean: mean of the total dead sapwood organic matter or carbon for all the cells (Mg ha^{-1}).

DeadSapwoodSte: standard error of the total dead sapwood organic matter or carbon for all the cells (Mg ha^{-1}).

DeadHeartwoodMean: mean of the total dead heartwood organic matter or carbon for all the cells (Mg ha^{-1}).

DeadHeartwoodSte: standard error of the total dead heartwood organic matter or carbon for all the cells (Mg ha^{-1}).

DeadCRootMean: mean of the dead coarse root organic matter or carbon for all the cells (Mg ha^{-1}).

DeadCRootSte: standard error of the coarse root organic matter or carbon for all the cells (Mg ha^{-1}).

StableSoilMean: mean of the stable soil organic matter or carbon for all the cells (Mg ha^{-1}).

StableSoilSte: standard error of the stable soil root organic matter or carbon for all the cells (Mg ha^{-1}).

Example of Dead.out file(note the first lines are a header that appears with each output file, listing variables in the order they appear in columns):

ModelNum, FileNum, Time, DeadFoliageMean, DeadFoliageSte, DeadFRootMean, DeadFRootSte, DeadBranchMean, DeadBranchSte, DeadSapMean, DeadSapSte, DeadHeartMean, DeadHeartSte, DeadCRootMean, CeadCRootSte, StableSoilMean, StableSoilSte

```
ML02  33    1.0    0.010   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  302.231    0.000
ML02  33    2.0    0.040   0.000    0.007   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  300.510    0.000
ML02  33    3.0    0.126   0.000    0.036   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  298.799    0.000
ML02  33    4.0    0.388   0.000    0.132   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  297.099    0.000
ML02  33    5.0    1.144   0.000    0.416   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  295.411    0.000
ML02  33    6.0    3.324   0.000    1.234   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  293.702    0.000
ML02  33    7.0    9.189   0.000    3.425   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  291.822    0.000
ML02  33    8.0   17.768   0.000    6.609   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  289.790    0.000
ML02  33    9.0   23.368   0.000    8.657   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  287.770    0.000
ML02  33   10.0   27.934   0.000   10.325   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  285.797    0.000
ML02  33   11.0   27.633   0.000   10.230   0.000    0.000   0.000    0.000   0.000    0.000   0.000    0.000   0.000  283.868    0.000
.........................................................................................................................................
ML02  33   46.0   21.278   0.000   48.272   0.000   11.606   0.000   16.260   0.000   10.711   0.000   22.542   0.000  239.807    0.000
ML02  33   47.0   21.519   0.000   48.353   0.000   12.185   0.000   16.954   0.000   11.701   0.000   23.574   0.000  239.310    0.000
ML02  33   48.0   21.753   0.000   48.451   0.000   12.752   0.000   17.642   0.000   12.736   0.000   24.605   0.000  238.840    0.000
ML02  33   49.0   21.976   0.000   48.556   0.000   13.306   0.000   18.322   0.000   13.816   0.000   25.634   0.000  238.396    0.000
ML02  33   50.0   22.184   0.000   48.660   0.000   13.845   0.000   18.993   0.000   14.940   0.000   26.658   0.000  237.977    0.000-
```

Volume.out

This file gives the cubic volume and the amount of volume that was harvested in a given year. In addition, the mean age and height of the upper tree layer is output as an indicator of wood value When the single cell version of the model is used only the mean stores are output and the standard error is set to zero. When the multicell version is used then the mean and the standard error are output.

The variables defined in the order they appear in the file are:

Model Number: ML02 indicates this file is output for STANDCARB.

Output File Number: 34 indicates this is the Volume.out file

Time: simulation year. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variables will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs then the effects of this disturbance will be calculated and output for time Year.04. This allows one to directly track that changes in stores for each disturbance in a given year.

Harvest: mean volume of trees harvested (cubic meters ha^{-1}).

Height: mean height of harvested trees (m).

Age: mean age of trees harvested, based on the upper tree layer (years).

Treatment: type of harvest treatment used.

PercentCut: percent on the trees that are cut on a cell (%).

PercentTake: percent of boles cut that is removed (%).

PercentCellsCut: percent of the cells that were cut by particular treatment (%).

Utilization: utlization level that was specificed.

FireType: fire type used for site preparation.

Example of Volume.out file (note the first lines are a header that appears with each output file, listing variables in the order they appear in columns):

ModelNum, FileNum, Time, Harvest, Height, Age, Treatment, PercentCut, PercentTake, PercentCellsCut, Utilization, FireType

```
ML02  34  100.2     533.63    38.14    50.00   ccut  100.0    85.0  100.0 high none
ML02  34  150.2     533.63    38.14    50.00   ccut  100.0    85.0  100.0 high none
ML02  34  200.2     533.63    38.14    50.00   ccut  100.0    85.0  100.0 high none
ML02  34  250.2     533.63    38.14    50.00   ccut  100.0    85.0  100.0 high none
ML02  34  300.2     533.63    38.14    50.00   ccut  100.0    85.0  100.0 high none
```

Diagnostic Files

The diagnostic files are used to examine specific subfunctions of the model for parameterization or trouble shooting purposes. The extension on these files is DGN. Diagnostic files are output when selected in the Simul.drv file.

Table 5. List of diagnostic files available to check the STANDCARB model behavior.

File Name	Purpose
Plant.dgn	checks rate layers and species are planted in cells
DieOut.dgn	checks the rate species die out of cells
Replace.dgn	checks the rate species are replaced during succession
Intercpt.dgn	outputs the interception of water by detrital pools and the canopy
WaterBal.dgn	outputs the moisture content of the detrital pools and soil
Transpir.dgn	outputs the transpiration of water
TempResp.dgn	response of decomposition and respiration to temperature
MoistRsp.dgn	response of detrital pool and soil decomposition to moisture
WPotResp.dgn	response of water potential and plant production to soil water
AbioResp.dgn	outputs indices of decomposition and growth for site
Light.dgn	outputs mean light interception by foliage of plant layers
Resp.dgn	outputs the respiration and mass of live plant parts
Mort.dgn	outputs detritus production (litterfall)
SubQual.dgn	outputs substrate quality of detritus added to detritus pools
Species.dgn	outputs the species in upper and lower tree layers
Neighbor.dgn	outputs incoming radiation for each cell for a given year
Species.dgn	outputs upper and lower tree species and upper tree height and age for each cell

Plant.dgn

This diagnostic file gives the number of cells occupied by plant layers (herb, shrub, upper tree, and lower tree) and tree species in each tree layer. For this diagnostic, the model allows layers and species to be planted, but does not allow them to die out. Therefore once a layer of species occupies a cell, it can not be removed. *Note that this diagnostic can not be run if either the DieOut or Replace diagnostic is being run.*

Time: year being simulated. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Herb: number of cells with herbs.

Shrubs: number of cells with shrubs.

UpperTree: number of cells with upper trees.

LowerTree: number of cells with lower trees.

Species specific data then repeats in the following order:

SpeciesA: species code.

SpeciesATotal: total number of cells that has species A. If a species occurs in the upper or lower tree layers or both layers of a cell it gets a value of 1. This variable indicates the presence or absence of a species in a cell.

SpeciesAUpperTrees: number of cells that has species A in upper tree layer.

SpeciesALowerTrees: number of cells that has species A in lower tree layer.

Example Plant.dgn file

Plant.dgn

Time, NumHerbs, NumShrubs, NumUpperTrees, NumLowerTrees, Species, SpeciesTotal, SpeciesNumUTrees, SpeciesNumLTrees

```
10.0      100       99        9        1
 ABPR       3        2        1
 ALRU       1        1        0
 CADE       1        1        0
 PREM       2        2        0
 PSME       3        3        0

 20.0     100       99       38       11
 ABPR      10        8        2
 ACMA       2        2        0
 ALRU      13        8        5
 ARME       1        1        0
 CACH       2        2        0
 CADE       1        1        0
 PILA       3        2        1
 POTR       2        2        0
 PREM       8        7        1
 PSME       7        5        2

 30.0     100       90       57       22
 ABPR      15       11        4
 ACMA       4        2        2
 ALRU      20       13        7
 ARME       1        1        0
 CACH       4        3        1
 CADE       1        1        0
 PILA       3        2        1
 PIMO       2        1        1
 POTR       3        3        0
 PREM      11        9        2
 PSME      15       11        4

 40.0      99       86       67       31
 ABPR      23       13       10
 ACMA       6        3        3
 ALRU      20       14        6
 ARME       1        1        0
 CACH      10        5        5
 CADE       1        1        0
 PILA       4        3        1
 PIMO       3        2        1
 POTR       3        3        0
 PREM      11       10        1
 PSME      16       12        4

 50.0     100       93       76       33
 ABPR      26       14       12
 ACMA       4        3        1
 ALRU      19       14        5
 ARME       1        1        0
 CACH       7        5        2
 CADE       1        1        0
 PILA       4        3        1
 PIMO       3        2        1
 POTR       7        6        1
 PREM      16       12        4
 PSME      21       15        6
```

DieOut.dgn

This diagnostic file gives the number of cells occupied by plant layers (herb, shrub, upper tree, and lower tree) and tree species in each tree layer. For this diagnostic, the model allows layers and species to be planted, but does not allow them to be replaced when they die out of a cell. Therefore once a layer of species dies out of a cell, it can not be replaced. Note: This diagnostic can not be run if either the Plant or Replace diagnostics are being run.

Time: year being simulated. If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Herb: number of cells with herbs.

Shrubs: number of cells with shrubs.

UpperTree: number of cells with upper trees.

LowerTree: number of cells with lower trees.

Species specific data then repeats in the following order:

SpeciesA: species code.

SpeciesATotal: total number of cells that has species A. If a species occurs in the upper or lower tree layers or both layers of a cell it gets a value of 1. This variable indicates the presence or absence of a species in a cell.

SpeciesAUpper Trees: number of cells that has species A in upper tree layer.

SpeciesALower Trees: number of cells that has species A in lower tree layer.

Example DieOut.dgn file

DieOut.dgn

Time, NumHerbs, NumShrubs, NumUpperTrees, NumLowerTrees, Species, SpeciesTotal, SpeciesNumUTrees, SpeciesNumLTrees

```
 10.0     100      99        9        1
ABPR        3       2        1
ALRU        1       1        0
CADE        1       1        0
PREM        2       2        0
PSME        3       3        0

20.0      100      99       38       11
ABPR       10       8        2
ACMA        2       2        0
ALRU       13       8        5
ARME        1       1        0
CACH        2       2        0
CADE        1       1        0
PILA        3       2        1
POTR        2       2        0
PREM        8       7        1
PSME        7       5        2

30.0      100      90       57       22
ABPR       15      11        4
ACMA        4       2        2
ALRU       20      13        7
ARME        1       1        0
CACH        4       3        1
CADE        1       1        0
PILA        3       2        1
PIMO        2       1        1
POTR        3       3        0
PREM       11       9        2
PSME       15      11        4

40.0       99      86       67       31
ABPR       23      13       10
ACMA        6       3        3
ALRU       20      14        6
ARME        1       1        0
CACH       10       5        5
CADE        1       1        0
PILA        4       3        1
PIMO        3       2        1
POTR        3       3        0
PREM       11      10        1
PSME       16      12        4

50.0      100      93       76       33
ABPR       26      14       12
ACMA        4       3        1
ALRU       19      14        5
ARME        1       1        0
CACH        7       5        2
CADE        1       1        0
PILA        4       3        1
PIMO        3       2        1
POTR        7       6        1
PREM       16      12        4
PSME       21      15        6
```

Replace.dgn

This diagnostic file gives the number of cells occupied by plant layers (herb, shrub, upper tree, and lower tree) and tree species in each tree layer. For this diagnostic, the model allows layers and species to be planted and die out as in the normal simulation run. This diagnostic can not be run if either the Plant or DieOut diagnostic is being run.

Time: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Herb: number of cells with herbs.

Shrubs: number of cells with shrubs.

UpperTree: number of cells with upper trees.

LowerTree: number of cells with lower trees.

Species specific data then repeats in the following order:

SpeciesA: species code.

SpeciesATotal: total number of cells that has species A. If a species occurs in the upper or lower tree layers or both layers of a cell it gets a value of 1. This variable indicates the presence or absence of a species in a cell.

SpeciesAUpperTrees: number of cells that has species A in upper tree layer.

SpeciesALowerTrees: number of cells that has species A in lower tree layer.

Example Replace.dgn file

Replace.dgn

Time, NumHerbs, NumShrubs, NumUpperTrees, NumLowerTrees, Species, SpeciesTotal, SpeciesNumUTrees, SpeciesNumLTrees

```
10.0      100       99        9         1
  ABPR       3         2        1
  ALRU       1         1        0
  CADE       1         1        0
  PREM       2         2        0
  PSME       3         3        0

  20.0     100        99       38        11
  ABPR      10         8        2
  ACMA       2         2        0
  ALRU      13         8        5
  ARME       1         1        0
  CACH       2         2        0
  CADE       1         1        0
  PILA       3         2        1
  POTR       2         2        0
  PREM       8         7        1
  PSME       7         5        2

  30.0     100        90       57        22
  ABPR      15        11        4
  ACMA       4         2        2
  ALRU      20        13        7
  ARME       1         1        0
  CACH       4         3        1
  CADE       1         1        0
  PILA       3         2        1
  PIMO       2         1        1
  POTR       3         3        0
  PREM      11         9        2
  PSME      15        11        4

  40.0      99        86       67        31
  ABPR      23        13       10
  ACMA       6         3        3
  ALRU      20        14        6
  ARME       1         1        0
  CACH      10         5        5
  CADE       1         1        0
  PILA       4         3        1
  PIMO       3         2        1
  POTR       3         3        0
  PREM      11        10        1
  PSME      16        12        4

  50.0     100        93       76        33
  ABPR      26        14       12
  ACMA       4         3        1
  ALRU      19        14        5
  ARME       1         1        0
  CACH       7         5        2
  CADE       1         1        0
  PILA       4         3        1
  PIMO       3         2        1
  POTR       7         6        1
  PREM      16        12        4
  PSME      21        15        6
```

Intercpt.dgn

This file contains the interception values for the canopy and detrital pools and monthly runoff for the temperature, precipitation, soil, and radiation conditions of the site. This diagnostic is only available for the single cell version of the model.

Year: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Month: month being simulated.

Temp24: temperature for month (C).

Prec: precipitation for month (cm).

SolRad: mean daily total solar radiation for month (cal cm^{-2} day^{-1}).

CanInterception: canopy interception for the month (cm).

DeadBranchInterception: interception of dead branch pool for the month (cm).

DeadSapwoodInterception: interception of dead sapwood pool for the month (cm).

DeadHeartInterception: interception of dead heartwood pool for the month (cm).

Dead FoliageInterception: interception of the dead foliage layer for a month (cm).

TotalInterception: total interception for the month (cm).

Runoff: water exceeding soil water holding capacity for the month (cm).

Example of Intercpt.dgn file:

Intercpt.dgn
Year, Month, Temp24, Precip, SolRad, CanIntercept
DeadBranchIntercept, DeadSapwoodIntercept, DeadHeartIntercept
DeadForestFloorInterception, TotalIntercept, Runoff

```
  1   1     0.30  39.00    114.70   0.000    0.000    0.000    0.000   0.000   0.000       0.00
  1   2     2.70  27.00    171.10   0.000    0.000    0.000    0.000   0.000   0.000      23.25
  1   3     3.80  27.00    267.70   0.000    0.000    0.000    0.000   0.000   0.000      27.00
  1   4     7.40  14.00    353.60   0.000    0.000    0.000    0.000   0.000   0.000      14.00
  1   5    11.70  11.00    473.70   0.000    0.000    0.000    0.000   0.000   0.000      11.00
  1   6    14.90   6.00    512.40   0.000    0.000    0.000    0.000   0.000   0.000       6.00
  1   7    18.30   1.00    590.20   0.000    0.000    0.000    0.000   0.000   0.000       1.00
  1   8    17.40   4.00    496.20   0.000    0.000    0.000    0.000   0.000   0.000       4.00
  1   9    13.50   8.00    365.50   0.000    0.000    0.000    0.000   0.000   0.000       8.00
  1  10     8.10  18.00    233.60   0.000    0.000    0.000    0.000   0.000   0.000      18.00
  1  11     3.50  34.00    129.10   0.000    0.000    0.000    0.000   0.000   0.000      34.00
  1  12     1.10  41.00     98.89   0.000    0.000    0.000    0.000   0.000   0.000      41.00
...............................................................................................
 50   1     0.30  39.00    114.70   4.674    0.002    0.004    0.001   0.017   4.697      33.52
 50   2     2.70  27.00    171.10   3.236    0.012    0.021    0.022   0.014   3.305      22.29
 50   3     3.80  27.00    267.70   3.236    0.010    0.015    0.004   0.076   3.340      20.94
 50   4     7.40  14.00    353.60   1.678    0.022    0.033    0.010   0.155   1.897       7.45
 50   5    11.70  11.00    473.70   1.318    0.054    0.081    0.024   0.360   1.838       0.76
 50   6    14.90   6.00    512.40   0.719    0.070    0.097    0.036   0.547   1.469       0.00
 50   7    18.30   1.00    590.20   0.120    0.012    0.016    0.006   0.482   0.636       0.00
 50   8    17.40   4.00    496.20   0.479    0.047    0.065    0.024   0.815   1.430       0.00
 50   9    13.50   8.00    365.50   0.959    0.094    0.129    0.049   0.106   1.336       0.00
 50  10     8.10  18.00    233.60   2.157    0.142    0.290    0.109   0.725   3.423       0.00
 50  11     3.50  34.00    129.10   4.074    0.020    0.067    0.031   0.055   4.248      22.56
 50  12     1.10  41.00     98.89   4.913    0.009    0.013    0.004   0.071   5.010      35.24
```

WaterBal.dgn

This file contains the moisture content of the detrital pools and soil. These are for the temperature, precipitation, soil, and radiation conditions of the site. This diagnostic is only available for the single cell version of the model.

Year: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Month: month being simulated.

Temp24: temperature for month (C).

Prec: precipitation for month (cm).

SolRad: daily mean solar radiation for month (cal cm^{-2} day^{-1}).

DeadFoliageMoist: moisture content of the dead foliage pool for each month (% mass basis).

DeadFineRootMoist: moisture content of the dead fine root pool for each month (% mass basis).

DeadBranchMoist: moisture content of the dead branch pool for each month (% mass basis).

DeadSapwoodMoist: moisture content of the dead sapwood pool for each month (% mass basis).

DeadHeartWoodMoist: moisture content of the dead heartwood pool for each month (% mass basis).

DeadCoarseRootMoist: moisture content of the dead coarse root pool for each month (% mass basis).

SoilMoist: moisture content of the mineral soil pool for each month (% volumetric basis).

Example WaterBal.dgn file:

WaterBal.dgn

Year, Month, Temp24, Precip, SolRad, DeadFoliageMoist, DeadFineRootMoist, DeadBranchMoist, DeadSapwoodMoist, DeadHeartwoodMoist, DeadCRootMoist, SoilMoist

```
  1  1    0.30  39.00 114.70   0.00    0.00    0.00    0.00    0.00    0.00    91.23
  1  2    2.70  27.00 171.10   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  3    3.80  27.00 267.70   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  4    7.40  14.00 353.60   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  5   11.70  11.00 473.70   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  6   14.90   6.00 512.40   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  7   18.30   1.00 590.20   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  8   17.40   4.00 496.20   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1  9   13.50   8.00 365.50   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1 10    8.10  18.00 233.60   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1 11    3.50  34.00 129.10   0.00    0.00    0.00    0.00    0.00    0.00   100.00
  1 12    1.10  41.00  98.89   0.00    0.00    0.00    0.00    0.00    0.00   100.00
.....................................................................................
 50  1    0.30  39.00 114.70 393.48  393.48  191.19  288.34  184.21  199.61   100.00
 50  2    2.70  27.00 171.10 365.47  365.47  192.49  292.01  197.02  199.72   100.00
 50  3    3.80  27.00 267.70 329.37  329.37  183.36  282.18  192.99  198.62   100.00
 50  4    7.40  14.00 353.60 236.27  236.27  159.22  255.71  182.33  191.69   100.00
 50  5   11.70  11.00 473.70 151.23  151.23  125.00  214.98  164.64  171.88   100.00
 50  6   14.90   6.00 512.40 180.65  180.65   96.70  169.33  147.06  146.65    86.42
 50  7   18.30   1.00 590.20  29.34   29.34   16.74   68.42   95.87   32.08    58.24
 50  8   17.40   4.00 496.20 351.88  351.88   39.66   68.19   84.51   71.46    47.63
 50  9   13.50   8.00 365.50  70.16   70.16   93.44  118.42  105.12  143.23    56.13
 50 10    8.10  18.00 233.60 374.78  374.78  184.97  263.40  177.38  198.87    85.67
 50 11    3.50  34.00 129.10 367.83  367.83  192.90  292.86  197.20  199.75   100.00
 50 12    1.10  41.00  98.89 392.40  392.40  198.22  298.09  199.25  199.98   100.00¬
```

Transpir.dgn

This diagnostic outputs the monthly transpiration caused by foliage of all layers. This diagnostic is only available for the single cell version of the model.

Year: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Month: month being simulated.

Temp24: temperature for month (C).

Prec: precipitation for month (cm).

SolRad: daily mean solar radiation for month (cal cm^{-2} day^{-1}):

PETTotal: the potential evapotranspiration of the site based on temperature and radiation (cm).

PotenTrans: the potential transpiration if foliage mass is at its maximum in a cell and soil water supply is not limiting (cm).

Transpiration: actual transpiration given the current foliage mass and soil water potential (cm). Actual transpiration can be limited by a low foliage mass or low soil moisture.

Example Transpir.dgn file:

Transpir.dgn

Year, Month, Temp24, Precip, SolRad, PETTotal, PotenTrans, Transpiration

```
 1  1   0.30  39.00  114.70    0.869    0.782    0.000
 1  2   2.70  27.00  171.10    1.562    1.406    0.000
 1  3   3.80  27.00  267.70    3.018    2.716    0.000
 1  4   7.40  14.00  353.60    5.168    4.651    0.000
 1  5  11.70  11.00  473.70    9.337    8.403    0.000
 1  6  14.90   6.00  512.40   11.486   10.338    0.000
 1  7  18.30   1.00  590.20   15.851   14.266    0.000
 1  8  17.40   4.00  496.20   12.840   11.556    0.000
 1  9  13.50   8.00  365.50    7.658    6.892    0.000
 1 10   8.10  18.00  233.60    3.702    3.332    0.000
 1 11   3.50  34.00  129.10    1.369    1.232    0.000
 1 12   1.10  41.00   98.89    0.833    0.749    0.000
..............................................................
50  1   0.30  39.00  114.70    0.869    0.782    0.782
50  2   2.70  27.00  171.10    1.562    1.406    1.406
50  3   3.80  27.00  267.70    3.018    2.716    2.716
50  4   7.40  14.00  353.60    5.168    4.651    4.651
50  5  11.70  11.00  473.70    9.337    8.403    8.403
50  6  14.90   6.00  512.40   11.486   10.338   10.338
50  7  18.30   1.00  590.20   15.851   14.266   12.407
50  8  17.40   4.00  496.20   12.840   11.556    7.108
50  9  13.50   8.00  365.50    7.658    6.892    3.032
50 10   8.10  18.00  233.60    3.702    3.332    1.946
50 11   3.50  34.00  129.10    1.369    1.232    1.067
50 12   1.10  41.00   98.89    0.833    0.749    0.749
```

TempResp.dgn

This file contains the response of decomposition, plant respiration, and growth to temperature assuming a systematic progression of temperature values is used (0-50 C by 1 C increments) rather than the values in the Climate.drv file.

Temperature: temperature (C)

DeadFoliageTempDecayIndex: value of index for response to temperature of dead foliage pool (dimensionless).

DeadFineRootTempDecayIndex: value of index for response to temperature of dead fine root pool (dimensionless).

DeadBranchTempDecayIndex: value of index for response to temperature of dead branch pool (dimensionless).

DeadSapwoodTempDecayIndex: value of index for response to temperature of dead sapwood pool (dimensionless).

DeadHeartWoodTempDecayIndex: value of index for response to temperature of dead heartwood pool (dimensionless).

DeadCRootTempDecayIndex: value of index for response to temperature of dead coarse root pool (dimensionless).

StableSoilTempDecayIndex: value of index for response to temperature of stable soil pool (dimensionless).

FineRootRespRate: value of the respiration rate for fine roots of the tree layers ($year^{-1}$).

BranchRespRate: value of the respiration rate for branch of the tree layers ($year^{-1}$).

SapwoodRespRate: value of the respiration rate for sapwood of the tree layers ($year^{-1}$).

CRootRespRate: value of the respiration rate for coarse roots of the tree layers ($year^{-1}$).

Example of TempResp.dgn file:

TempResp.dgn

Temp, DeadFoliageTmpDcayIndx, DeadFRootTmpDcayInex, DeadBranchTmpDcayIndx, DeadSapTmpDcayIndx, DeadHeartTmpDcayIndx, DeadCoarseRootTmpDcayIndx, SoilTmpDcayIndx, FRootRespRate, BranchRespRate, SapwoodRespRate, CRootRespRate

```
 0.0   0.500  0.500  0.500  0.500  0.500  0.500  0.500  0.250  0.009  0.009  0.009
 1.0   0.536  0.536  0.536  0.536  0.536  0.536  0.536  0.268  0.009  0.009  0.009
 2.0   0.574  0.574  0.574  0.574  0.574  0.574  0.574  0.287  0.010  0.010  0.010
 3.0   0.616  0.616  0.616  0.616  0.616  0.616  0.616  0.308  0.010  0.010  0.010
 4.0   0.660  0.660  0.660  0.660  0.660  0.660  0.660  0.330  0.011  0.011  0.011
 5.0   0.707  0.707  0.707  0.707  0.707  0.707  0.707  0.354  0.012  0.012  0.012
 6.0   0.758  0.758  0.758  0.758  0.758  0.758  0.758  0.379  0.013  0.013  0.013
 7.0   0.812  0.812  0.812  0.812  0.812  0.812  0.812  0.406  0.014  0.014  0.014
 8.0   0.871  0.871  0.871  0.871  0.871  0.871  0.871  0.435  0.015  0.015  0.015
 9.0   0.933  0.933  0.933  0.933  0.933  0.933  0.933  0.467  0.016  0.016  0.016
10.0   1.000  1.000  1.000  1.000  1.000  1.000  1.000  0.500  0.017  0.017  0.017
11.0   1.072  1.072  1.072  1.072  1.072  1.072  1.072  0.536  0.018  0.018  0.018
12.0   1.149  1.149  1.149  1.149  1.149  1.149  1.149  0.574  0.020  0.020  0.020
13.0   1.231  1.231  1.231  1.231  1.231  1.231  1.231  0.616  0.021  0.021  0.021
14.0   1.320  1.320  1.320  1.320  1.320  1.320  1.320  0.660  0.022  0.022  0.022
15.0   1.414  1.414  1.414  1.414  1.414  1.414  1.414  0.707  0.024  0.024  0.024
16.0   1.516  1.516  1.516  1.516  1.516  1.516  1.516  0.758  0.026  0.026  0.026
17.0   1.624  1.624  1.624  1.624  1.624  1.624  1.624  0.812  0.028  0.028  0.028
18.0   1.741  1.741  1.741  1.741  1.741  1.741  1.741  0.871  0.030  0.030  0.030
19.0   1.866  1.866  1.866  1.866  1.866  1.866  1.866  0.933  0.032  0.032  0.032
20.0   2.000  2.000  2.000  2.000  2.000  2.000  2.000  1.000  0.034  0.034  0.034
21.0   2.143  2.143  2.143  2.143  2.143  2.143  2.143  1.072  0.036  0.036  0.036
22.0   2.297  2.297  2.297  2.297  2.297  2.297  2.297  1.149  0.039  0.039  0.039
23.0   2.461  2.461  2.461  2.461  2.461  2.461  2.461  1.231  0.042  0.042  0.042
24.0   2.637  2.637  2.637  2.637  2.637  2.637  2.637  1.320  0.045  0.045  0.045
25.0   2.825  2.825  2.825  2.825  2.825  2.825  2.825  1.414  0.048  0.048  0.048
26.0   3.025  3.025  3.025  3.025  3.025  3.025  3.025  1.516  0.052  0.052  0.052
27.0   3.236  3.236  3.236  3.236  3.236  3.236  3.236  1.625  0.055  0.055  0.055
28.0   3.458  3.458  3.458  3.458  3.458  3.458  3.458  1.741  0.059  0.059  0.059
29.0   3.689  3.689  3.689  3.689  3.689  3.689  3.689  1.866  0.063  0.063  0.063
30.0   3.923  3.923  3.923  3.923  3.923  3.923  3.923  2.000  0.068  0.068  0.068
31.0   4.152  4.152  4.152  4.152  4.152  4.152  4.152  2.144  0.073  0.073  0.073
32.0   4.364  4.364  4.364  4.364  4.364  4.364  4.364  2.297  0.078  0.078  0.078
33.0   4.539  4.539  4.539  4.539  4.539  4.539  4.539  2.462  0.084  0.084  0.084
34.0   4.645  4.645  4.645  4.645  4.645  4.645  4.645  2.639  0.090  0.090  0.090
35.0   4.644  4.644  4.644  4.644  4.644  4.644  4.644  2.828  0.096  0.096  0.096
36.0   4.487  4.487  4.487  4.487  4.487  4.487  4.487  3.031  0.103  0.103  0.103
37.0   4.127  4.127  4.127  4.127  4.127  4.127  4.127  3.249  0.110  0.110  0.110
38.0   3.538  3.538  3.538  3.538  3.538  3.538  3.538  3.482  0.118  0.118  0.118
39.0   2.746  2.746  2.746  2.746  2.746  2.746  2.746  3.732  0.127  0.127  0.127
40.0   1.854  1.854  1.854  1.854  1.854  1.854  1.854  4.000  0.136  0.136  0.136
41.0   1.032  1.032  1.032  1.032  1.032  1.032  1.032  4.287  0.146  0.146  0.146
42.0   0.440  0.440  0.440  0.440  0.440  0.440  0.440  4.595  0.156  0.156  0.156
43.0   0.130  0.130  0.130  0.130  0.130  0.130  0.130  4.925  0.167  0.167  0.167
44.0   0.024  0.024  0.024  0.024  0.024  0.024  0.024  5.278  0.179  0.179  0.179
45.0   0.002  0.002  0.002  0.002  0.002  0.002  0.002  5.657  0.192  0.192  0.192
46.0   0.000  0.000  0.000  0.000  0.000  0.000  0.000  6.063  0.206  0.206  0.206
47.0   0.000  0.000  0.000  0.000  0.000  0.000  0.000  6.498  0.221  0.221  0.221
48.0   0.000  0.000  0.000  0.000  0.000  0.000  0.000  6.964  0.237  0.237  0.237
49.0   0.000  0.000  0.000  0.000  0.000  0.000  0.000  7.464  0.254  0.254  0.254
50.0   0.000  0.000  0.000  0.000  0.000  0.000  0.000  8.000  0.272  0.272  0.272¬
```

MoistRsp.dgn

This file contains the response of decomposition to moisture assuming a systematic progression of moisture values is used (0-500 % by 5 % increments) rather than the values computed from the WaterBalance functions.

Moisture: moisture of the detrital pool or soil (%).

DeadFoliageMoistureDecayIndex: value of index for response to moisture of dead foliage pool (dimensionless).

DeadFineRootMoistureDecayIndex: value of index for response to moisture of dead fine root pool (dimensionless).

DeadBranchMoistureDecayIndex: value of index for response to moisture of dead branch pool (dimensionless).

DeadSapwoodMoistureDecayIndex: value of index for response to moisture of dead sapwood pool (dimensionless).

DeadHeartWoodMoistureDecayIndex: value of index for response to moisture of dead heartwood pool (dimensionless).

DeadCRootMoistureDecayIndex: value of index for response to moisture of dead coarse root pool (dimensionless).

StableSoilMoistureDecayIndex: value of index for response to moisture of stable soil pool (dimensionless).

Example of MoistRsp.dgn file:

MoistResp.dgn

Moisture, DeadFoliageMoistDcayIndx, DeadFRootMoistDcayIndx, DeadBranchMoistDcayIndx, DeadSapMoistDcayIndx, DeadHeartMoistDcayIndx, DeadCRootMoistDcayIndx, SoilMoistDcayIndx

```
  0.00    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  5.00    0.009    0.009    0.009    0.009    0.009    0.009    0.101
 10.00    0.101    0.101    0.101    0.101    0.101    0.101    0.483
 15.00    0.283    0.283    0.283    0.283    0.283    0.283    0.775
 20.00    0.483    0.483    0.483    0.483    0.483    0.483    0.912
 25.00    0.652    0.652    0.652    0.652    0.652    0.652    0.967
 30.00    0.775    0.775    0.775    0.775    0.775    0.775    0.988
 35.00    0.858    0.858    0.858    0.858    0.858    0.858    0.995
 40.00    0.912    0.912    0.912    0.912    0.912    0.912    0.998
 45.00    0.946    0.946    0.946    0.946    0.946    0.946    0.999
 50.00    0.967    0.967    0.967    0.967    0.967    0.967    1.000
 55.00    0.980    0.980    0.980    0.980    0.980    0.980    1.000
 60.00    0.988    0.988    0.988    0.988    0.988    0.988    1.000
 65.00    0.993    0.993    0.993    0.993    0.993    0.993    0.999
 70.00    0.995    0.995    0.995    0.995    0.995    0.995    0.997
 75.00    0.997    0.997    0.997    0.997    0.997    0.997    0.993
 80.00    0.998    0.998    0.998    0.998    0.998    0.998    0.981
 85.00    0.999    0.999    0.999    0.999    0.999    0.999    0.953
 90.00    0.999    0.999    0.999    0.999    0.999    0.999    0.892
 95.00    1.000    1.000    1.000    1.000    1.000    1.000    0.773
100.00    1.000    1.000    1.000    1.000    1.000    1.000    0.574
105.00    1.000    1.000    1.000    1.000    1.000    1.000    0.315
110.00    1.000    1.000    1.000    0.999    0.999    0.999    0.098
115.00    1.000    1.000    1.000    0.999    0.999    0.999    0.011
120.00    1.000    1.000    1.000    0.997    0.997    0.997    0.000
125.00    1.000    1.000    1.000    0.995    0.995    0.995    0.000
130.00    1.000    1.000    1.000    0.992    0.992    0.992    0.000
135.00    1.000    1.000    1.000    0.986    0.986    0.986    0.000
140.00    1.000    1.000    1.000    0.975    0.975    0.975    0.000
145.00    1.000    1.000    1.000    0.958    0.958    0.958    0.000
150.00    1.000    1.000    1.000    0.932    0.932    0.932    0.000
155.00    1.000    1.000    0.999    0.891    0.891    0.891    0.000
160.00    1.000    1.000    0.999    0.830    0.830    0.830    0.000
165.00    1.000    1.000    0.998    0.745    0.745    0.745    0.000
170.00    1.000    1.000    0.998    0.630    0.630    0.630    0.000
175.00    1.000    1.000    0.996    0.490    0.490    0.490    0.000
180.00    1.000    1.000    0.994    0.337    0.337    0.337    0.000
185.00    1.000    1.000    0.991    0.194    0.194    0.194    0.000
190.00    1.000    1.000    0.987    0.087    0.087    0.087    0.000
195.00    1.000    1.000    0.981    0.027    0.027    0.027    0.000
200.00    1.000    1.000    0.973    0.005    0.005    0.005    0.000
205.00    1.000    1.000    0.961    0.000    0.000    0.000    0.000
210.00    1.000    1.000    0.944    0.000    0.000    0.000    0.000
215.00    0.999    0.999    0.921    0.000    0.000    0.000    0.000
220.00    0.999    0.999    0.891    0.000    0.000    0.000    0.000
225.00    0.999    0.999    0.850    0.000    0.000    0.000    0.000
230.00    0.998    0.998    0.798    0.000    0.000    0.000    0.000
235.00    0.998    0.998    0.732    0.000    0.000    0.000    0.000
240.00    0.997    0.997    0.652    0.000    0.000    0.000    0.000
245.00    0.996    0.996    0.559    0.000    0.000    0.000    0.000
250.00    0.995    0.995    0.455    0.000    0.000    0.000    0.000
255.00    0.993    0.993    0.346    0.000    0.000    0.000    0.000
260.00    0.990    0.990    0.242    0.000    0.000    0.000    0.000
265.00    0.987    0.987    0.151    0.000    0.000    0.000    0.000
270.00    0.983    0.983    0.082    0.000    0.000    0.000    0.000
275.00    0.978    0.978    0.037    0.000    0.000    0.000    0.000
280.00    0.971    0.971    0.013    0.000    0.000    0.000    0.000
```

WPotResp.dgn

This diagnostic file indicates the response of water potential and plant growth to soil water stores.

SoilWat: water stores in soil (cm)

WaterPot: water potential of the soil (Mpascals).

MoistProdIndex: moisture production index of the upper trees (dimensionless).

Example of WpotResp.dgn file:

WPotResp.dgn

SoilWater, WaterPotential, MoistProdIndex

```
   5.000      2.168      0.000
   6.000      1.811      0.001
   7.000      1.557      0.004
   8.000      1.366      0.010
   9.000      1.217      0.020
  10.000      1.099      0.036
  11.000      1.002      0.059
  12.000      0.921      0.087
  13.000      0.852      0.120
  14.000      0.793      0.158
  15.000      0.742      0.199
  16.000      0.698      0.243
  17.000      0.659      0.289
  18.000      0.624      0.334
  19.000      0.592      0.380
  20.000      0.564      0.424
  21.000      0.539      0.467
  22.000      0.516      0.508
  23.000      0.495      0.547
  24.000      0.475      0.584
  25.000      0.458      0.618

  ...........................
  90.000      0.000      1.000
  91.000      0.000      1.000
  92.000      0.000      1.000
  93.000      0.000      1.000
  94.000      0.000      1.000
  95.000      0.000      1.000
  96.000      0.000      1.000
  97.000      0.000      1.000
  98.000      0.000      1.000
  99.000      0.000      1.000
 100.000      0.000      1.000
```

AbioResp.dgn

This file contains the response of decomposition and growth to the combined effects of temperature and moisture. These indices are calculated using the temperature, precipitation, soil, and radiation conditions of the site. This diagnostic is only available for the single cell version of the model.

Year: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Month: month being simulated.

Temp24: temperature for month (C).

Prec: precipitation for month (cm).

SolRad: mean daily solar radiation for month (cal cm^{-2} day^{-1}).

DeadFoliageAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead foliage decomposition rate (dimensionless).

DeadFineRootAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead fine root decomposition rate (dimensionless).

DeadBranchAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead branch decomposition rate (dimensionless).

DeadSapwoodAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead sapwood decomposition rate (dimensionless).

DeadHeartwoodAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead heartwood decomposition rate (dimensionless).

DeadCRootAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the dead coarse root decomposition rate (dimensionless).

StableSoilAbioticDecayIndex: value of the abiotic decay index that combines the effects of moisture and temperature on the stable soil decomposition rate (dimensionless).

HerbProdIndex: value of the abiotic production index for herbs that combines the effects of moisture and temperature on the growth rate (dimensionless).

ShrubProdIndex: value of the abiotic production index for shrubs that combines the effects of moisture and.temperature on the growth rate (dimensionless).

LowerTreeProdIndex: value of the abiotic production index for lower trees that combines the effects of moisture and temperature on the growth rate (dimensionless).

UpperTreeProdIndex: value of the abiotic production index for upper trees that combines the effects of moisture and temperature on the growth rate (dimensionless).

Example AbioResp.dgn file:

AbioResp.dgn
Year, Month, Temp24, Precip, SolRad, DeadFoliageAbioticDecayIndex, DeadFineRootAbioticDecayIndex, DeadBranchAbioticDecayIndex, DeadSapwoodAbioticDecayIndex, DeadHeartwoodAbioticDecayIndex, DeadCRootAbioticDecayIndex, StableSoilAbioticDecayIndex, ProdIndexHerb ProdIndexShrub, ProdIndexLTree, ProdIndexUtree

```
 1  1  0.30 39.00  114.70  0.000  0.000  0.000  0.000  0.000  0.000  0.444  0.000  0.000  0.000  0.000
 1  2  2.70 27.00  171.10  0.000  0.000  0.000  0.000  0.000  0.000  0.346  0.000  0.000  0.000  0.000
 1  3  3.80 27.00  267.70  0.000  0.000  0.000  0.000  0.000  0.000  0.373  0.000  0.000  0.000  0.000
 1  4  7.40 14.00  353.60  0.000  0.000  0.000  0.000  0.000  0.000  0.479  0.000  0.000  0.000  0.000
 1  5 11.70 11.00  473.70  0.000  0.000  0.000  0.000  0.000  0.000  0.646  0.000  0.000  0.000  0.000
 1  6 14.90  6.00  512.40  0.000  0.000  0.000  0.000  0.000  0.000  0.806  0.000  0.000  0.000  0.000
 1  7 18.30  1.00  590.20  0.000  0.000  0.000  0.000  0.000  0.000  1.020  0.000  0.000  0.000  0.000
 1  8 17.40  4.00  496.20  0.000  0.000  0.000  0.000  0.000  0.000  0.959  0.000  0.000  0.000  0.000
 1  9 13.50  8.00  365.50  0.000  0.000  0.000  0.000  0.000  0.000  0.731  0.000  0.000  0.000  0.000
 1 10  8.10 18.00  233.60  0.000  0.000  0.000  0.000  0.000  0.000  0.503  0.000  0.000  0.000  0.000
 1 11  3.50 34.00  129.10  0.000  0.000  0.000  0.000  0.000  0.000  0.366  0.000  0.000  0.000  0.000
 1 12  1.10 41.00   98.89  0.000  0.000  0.000  0.000  0.000  0.000  0.310  0.000  0.000  0.000  0.000
.......................................................................................................
50  1  0.30 39.00  114.70  0.004  0.004  0.503  0.000  0.110  0.003  0.293  0.000  0.000  0.000  0.000
50  2  2.70 27.00  171.10  0.120  0.120  0.594  0.000  0.009  0.003  0.346  0.000  0.000  0.096  0.096
50  3  3.80 27.00  267.70  0.464  0.464  0.646  0.000  0.030  0.006  0.373  0.000  0.000  0.352  0.352
50  4  7.40 14.00  353.60  0.833  0.833  0.834  0.000  0.223  0.051  0.479  0.000  0.000  0.466  0.466
50  5 11.70 11.00  473.70  1.125  1.125  1.125  0.000  0.846  0.653  0.646  0.000  0.000  0.732  0.732
50  6 14.90  6.00  512.40  1.404  1.404  1.404  0.909  1.333  1.336  1.320  0.000  0.000  0.801  0.801
50  7 18.30  1.00  590.20  1.352  1.352  0.629  1.768  1.777  1.446  1.777  0.000  0.000  0.609  0.609
50  8 17.40  4.00  496.20  0.670  0.670  1.518  1.661  1.668  1.664  1.670  0.000  0.000  0.435  0.435
50  9 13.50  8.00  365.50  1.269  1.269  1.274  1.272  1.274  1.230  1.274  0.000  0.000  0.582  0.582
50 10  8.10 18.00  233.60  0.083  0.083  0.869  0.000  0.366  0.007  0.830  0.000  0.000  0.847  0.847
50 11  3.50 34.00  129.10  0.108  0.108  0.627  0.000  0.009  0.004  0.366  0.000  0.000  0.775  0.775
50 12  1.10 41.00   98.89  0.005  0.005  0.527  0.000  0.004  0.003  0.310  0.000  0.000  0.415  0.415
```

Light.dgn

This file contains the light entering and leaving each plant layer in a cell for each annual time step. This diagnostic can be used with the single cell or multicell version of the model. In the case of the multicell version, the mean of all the cells is output.

Time: year being simulated.

UpperTreeLightIn: the fraction of full sunlight that enters a cell (dimensionless). In case of the multicell, interactive version the light entering a cell can be reduced by neighboring cells.

LowerTreeLightIn: the mean fraction of full sunlight the passes through the upper tree foliage and into the lower tree layer (dimensionlesss).

ShrubLightIn: the mean fraction of full sunlight the passes through the lower tree foliage and into the shrub layer (dimensionlesss).

HerbLightIn: the mean fraction of full sunlight the passes through the shrub foliage and into the herb layer (dimensionlesss).

HerbLightOut: the mean fraction of full sunlight the passes through the herb foliage (dimensionlesss).

Example of Light dgn file:

```
Light.dgn

Year, Row, Col, UTreeLightIn, LTreeLightIn, ShrubLightIn,
HerbLightIn, HerbLightOut

 1.0     0     0    1.000    1.000    1.000    1.000    0.998
  2.0     0     0    1.000    1.000    1.000    1.000    0.993
  3.0     0     0    1.000    0.999    0.999    0.999    0.978
  4.0     0     0    1.000    0.998    0.998    0.998    0.938
  5.0     0     0    1.000    0.997    0.997    0.997    0.828
  6.0     0     0    1.000    0.995    0.995    0.995    0.577
  7.0     0     0    1.000    0.992    0.992    0.992    0.239
.................................................................
 47.0     0     0    1.000    0.100    0.050    0.050    0.050
 48.0     0     0    1.000    0.100    0.050    0.050    0.050
 49.0     0     0    1.000    0.100    0.050    0.050    0.050
 50.0     0     0    1.000    0.100    0.050    0.050    0.050
```

Resp.dgn

This file contains the losses from respiration and the mass of the respiring pools for each annual time step. This diagnostic can be used with the single cell or multicell version of the model. In the latter case, the output variables represent a mean of all the cells.

Time: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

Foliage: mass of foliage (Mg ha^{-1}).

FoliageResp: mass of foliage allocation respired (Mg ha^{-1} yr^{-1}).

FineRoot: mass of fine roots (Mg ha^{-1}).

FineRootResp: mass of fine root allocation respired (Mg ha^{-1} yr^{-1}).

Branch: mass of branches (Mg ha^{-1}).

BranchResp: mass of branch allocation respired (Mg ha^{-1} yr^{-1}).

Sapwood: mass of sapwood (Mg ha^{-1}).

SapwoodResp: mass of sapwood allocation respired (Mg ha^{-1} yr^{-1}).

CoarseRoot: mass of coarse roots (Mg ha^{-1}).

CoarseRootResp: mass of coarse root allocation respired (Mg ha^{-1} yr^{-1}).

Example of Resp.dgn file:

Resp.dgn

Year, FoliageMass, FoliageResp, FineRootMass, FineRootResp, BranchMass, BranchResp, SapwoodMass, SapwoodResp, CoarseRootMass, CoarseRootResp

```
  1.0    0.030    0.005    0.015    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  2.0    0.090    0.014    0.060    0.000    0.000    0.000    0.000    0.000    0.000    0.000
  3.0    0.285    0.043    0.200    0.000    0.002    0.000    0.010    0.000    0.008    0.000
  4.0    0.830    0.126    0.611    0.000    0.006    0.000    0.024    0.000    0.019    0.000
  5.0    2.405    0.370    1.795    0.000    0.012    0.000    0.044    0.001    0.036    0.000
  6.0    6.235    1.080    4.672    0.000    0.020    0.000    0.074    0.001    0.061    0.001
  7.0   10.730    2.810    8.049    0.001    0.032    0.000    0.118    0.002    0.099    0.001
  8.0   12.340    4.838    9.266    0.001    0.050    0.000    0.184    0.003    0.155    0.002
  9.0   12.870    5.557    9.677    0.002    0.078    0.001    0.281    0.004    0.239    0.002
 10.0   13.105    5.789    9.865    0.002    0.140    0.001    0.442    0.006    0.388    0.004
 11.0   13.254    5.871   10.002    0.004    0.249    0.003    0.692    0.010    0.624    0.007
 12.0   13.416    5.910   10.157    0.007    0.443    0.006    1.089    0.015    1.009    0.012
 13.0   13.643    5.940   10.367    0.011    0.803    0.012    1.730    0.022    1.656    0.021
 14.0   13.982    5.978   10.658    0.018    1.491    0.024    2.791    0.033    2.771    0.037
 15.0   14.431    6.036   11.009    0.031    2.802    0.049    4.565    0.050    4.714    0.069
 16.0   14.588    6.100   11.133    0.053    5.022    0.100    7.383    0.074    7.865    0.129
 17.0   12.875    5.972   10.128    0.086    7.339    0.187   10.879    0.110   11.526    0.231
 18.0   13.375    4.928   11.146    0.106    8.644    0.273   14.425    0.160   14.684    0.339
 19.0   16.338    4.817   13.764    0.104   10.289    0.307   18.869    0.228   18.702    0.403
 20.0   14.101    5.780   12.753    0.132    5.201    0.349   18.409    0.315   16.293    0.484
 21.0   18.235    4.386   16.226    0.135    6.699    0.080   23.541    0.419   21.066    0.251
 22.0   16.287    5.919   15.072    0.158    8.332    0.103   29.005    0.536   26.307    0.324
 23.0   18.614    4.759   17.060    0.177   10.053    0.128   34.599    0.661   31.871    0.405
 24.0   16.259    5.592   15.482    0.192   11.826    0.155   40.169    0.788   37.636    0.490
 25.0   19.147    4.356   17.795    0.204   13.626    0.182   45.608    0.915   43.512    0.579
 26.0   15.651    5.530   15.291    0.213   15.443    0.210   50.851    1.039   49.433    0.669
 27.0   18.140    3.842   17.255    0.220   17.273    0.238   55.868    1.159   55.358    0.760
 28.0   18.502    4.879   17.616    0.226   19.130    0.266   60.659    1.274   61.267    0.852
 29.0   18.179    4.962   17.464    0.231   21.039    0.294   65.251    1.384   67.157    0.942
 30.0   19.135    4.735   18.282    0.237   23.043    0.324   69.698    1.490   73.047    1.033
 31.0   17.498    5.075   17.180    0.243   25.204    0.354   74.079    1.593   78.976    1.124
 32.0   19.731    4.222   19.012    0.251   27.598    0.388   78.497    1.696   84.996    1.215
 33.0   17.730    5.090   17.710    0.261   30.296    0.425   83.046    1.802   91.161    1.308
 34.0   18.551    4.011   18.531    0.272   33.312    0.466   87.761    1.912   97.485    1.402
 35.0   19.253    4.197   19.233    0.285   36.557    0.512   92.556    2.027  103.907    1.500
 36.0   19.693    4.356   19.673    0.296   39.870    0.562   97.257    2.146  110.307    1.598
 37.0   19.889    4.455   19.869    0.303   43.113    0.613  101.717    2.263  116.582    1.697
 38.0   19.957    4.500   19.937    0.306   46.225    0.663  105.876    2.375  122.682    1.793
 39.0   19.976    4.515   19.956    0.307   49.192    0.711  109.727    2.479  128.594    1.887
 40.0   19.979    4.519   19.959    0.307   52.015    0.757  113.287    2.576  134.319    1.978
 41.0   19.979    4.520   19.959    0.307   54.701    0.800  116.575    2.665  139.860    2.066
 42.0   19.977    4.520   19.957    0.307   57.257    0.841  119.614    2.748  145.224    2.152
 43.0   19.976    4.519   19.956    0.307   59.689    0.881  122.422    2.824  150.417    2.234
 44.0   19.975    4.519   19.955    0.307   62.004    0.918  125.018    2.895  155.443    2.314
 45.0   19.974    4.519   19.954    0.307   64.207    0.954  127.419    2.961  160.308    2.391
 46.0   19.973    4.519   19.953    0.307   66.304    0.988  129.639    3.021  165.018    2.466
 47.0   19.973    4.519   19.953    0.307   68.301    1.020  131.694    3.078  169.578    2.539
 48.0   19.973    4.518   19.953    0.307   70.203    1.051  133.596    3.130  173.992    2.609
 49.0   19.972    4.518   19.952    0.307   72.013    1.080  135.357    3.178  178.265    2.677
 50.0   19.972    4.518   19.952    0.307   73.737    1.108  136.987    3.223  182.401    2.742
```

Mort.dgn

This file contains the mass of mortality from all sources (pruning, mortality, thinning, dieout, fire) for each output interval. This diagnostic can be used with the single cell or multicell version of the model. In the latter case, the output variables represent a mean of all the cells.

Time: If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

DeadFoliageInput: mass of foliage dying and being added to the dead foliage pool (Mg ha^{-1} yr^{-1}).

DeadFineRootInput: mass of fine roots dying and being added to the dead fine root pool (Mg ha^{-1} yr^{-1}).

DeadBranchInput: mass of branches dying and being added to the dead branch pool (Mg ha^{-1} yr^{-1}).

DeadSapwoodInput: mass of sapwood dying and being added to the dead sapwood pool (Mg ha^{-1} yr^{-1}).

DeadHeartwoodInput: mass of heartwood dying and being added to the dead heartwood pool (Mg ha^{-1} yr^{-1}).

DeadCRootInput: mass of coarse roots dying and being added to the dead coarse roots pool (Mg ha^{-1} yr^{-1}).

StableSoilInput: mass of decomposed detritus being added to the stable soil pool (Mg ha^{-1} yr^{-1}).

Example of Mort.dgn file:

Mort.dgn

Time, DeadFoliageInput, DeadFRootInput, DeadBranchInput, DeadSapwoodInput, DeadHeartwoodInput, DeadCRootInput, StableSoilInput

```
 1.0    0.010    0.000    0.000    0.000    0.000    0.000    0.000
 2.0    0.030    0.007    0.000    0.000    0.000    0.000    0.000
 3.0    0.092    0.030    0.000    0.000    0.000    0.000    0.000
 4.0    0.273    0.100    0.000    0.000    0.000    0.000    0.001
 5.0    0.812    0.305    0.000    0.000    0.000    0.000    0.003
 6.0    2.378    0.897    0.000    0.000    0.000    0.000    0.009
 7.0    6.195    2.336    0.000    0.000    0.000    0.000    0.028
 8.0   10.670    4.025    0.000    0.000    0.000    0.000    0.078
 9.0   12.249    4.633    0.000    0.000    0.000    0.000    0.150
10.0   12.738    4.839    0.000    0.000    0.000    0.000    0.197
11.0   12.889    4.932    0.000    0.000    0.000    0.000    0.234
12.0   12.923    5.001    0.000    0.000    0.000    0.001    0.232
13.0   12.903    5.079    0.001    0.001    0.000    0.001    0.213
14.0   12.839    5.185    0.003    0.003    0.000    0.004    0.211
15.0   12.704    5.332    0.011    0.006    0.001    0.011    0.199
16.0   12.384    5.513    0.041    0.017    0.001    0.034    0.196
17.0   11.424    5.587    0.124    0.045    0.002    0.098    0.197
18.0    8.740    5.097    0.225    0.085    0.005    0.179    0.205
19.0    8.593    5.614    0.221    0.111    0.009    0.201    0.207
20.0   10.188    7.188    6.489    5.148    0.015    6.702    0.233
21.0    7.120    6.455    0.131    0.165    0.024    0.212    0.465
22.0   10.084    8.212    0.181    0.226    0.036    0.294    0.440
23.0    7.171    7.651    0.235    0.291    0.051    0.384    0.526
24.0    8.735    8.659    0.291    0.357    0.069    0.478    0.515
25.0    5.789    7.880    0.348    0.422    0.091    0.575    0.542
26.0    8.217    9.044    0.405    0.484    0.117    0.673    0.555
27.0    4.355    7.797    0.461    0.544    0.145    0.771    0.672
28.0    6.539    8.784    0.516    0.600    0.177    0.867    0.648
29.0    6.626    8.968    0.569    0.653    0.211    0.962    0.724
30.0    6.027    8.895    0.623    0.702    0.248    1.056    0.757
31.0    6.675    9.307    0.678    0.750    0.288    1.149    0.773
32.0    4.663    8.760    0.737    0.796    0.329    1.242    0.858
33.0    6.424   10.717    0.805    0.844    0.373    1.338    0.840
34.0    3.854    9.042    0.891    0.897    0.419    1.439    0.974
35.0    4.070    9.466    0.997    0.957    0.467    1.547    1.041
36.0    4.258    9.830    1.119    1.022    0.517    1.660    1.124
37.0    4.378   10.059    1.241    1.085    0.568    1.773    1.214
38.0    4.432   10.162    1.355    1.143    0.621    1.881    1.304
39.0    4.451   10.197    1.460    1.195    0.676    1.984    1.327
40.0    4.457   10.207    1.557    1.243    0.731    2.083    1.330
41.0    4.457   10.209    1.649    1.286    0.788    2.178    1.339
42.0    4.457   10.208    1.736    1.326    0.845    2.270    1.348
43.0    4.456   10.208    1.818    1.363    0.904    2.358    1.360
44.0    4.456   10.207    1.897    1.397    0.963    2.444    1.376
45.0    4.456   10.206    1.971    1.428    1.023    2.528    1.395
46.0    4.455   10.206    2.042    1.458    1.083    2.608    1.416
47.0    4.455   10.205    2.110    1.485    1.143    2.686    1.438
48.0    4.455   10.205    2.174    1.510    1.204    2.761    1.460
49.0    4.455   10.205    2.236    1.533    1.265    2.834    1.483
50.0    4.455   10.205    2.294    1.554    1.326    2.905    1.506
```

SubQual.dgn

This file contains the decomposition rate of each pool that is based only on substrate quality (PoolDecayRateAvg) for each annual time step. The effects of temperature and moisture are output by the AbioResp.dgn file. The SubQual diagnostic can be used with the single cell or multicell version of the model. In the latter case, the output variables represent a mean of all the cells.

Time:If a harvest activity or fire occurs in a given year several lines of output will be generated for that year. After the "normal" growth and decomposition processes have occurred, state variable will be output for the time Year.01. Then the effects of harvest will be calculated and output for the time Year.02. If site preparation fire after harvest occurs, then the effects of this disturbance will be calculated and output for time Year.03. If a wildfire occurs, then the effects of this disturbance will be calculated and output for time Year.04.

DeadFoliageDecayRateAvg: the combined substrate quality effects of all the dead foliage pools ($year^{-1}$).

DeadFineRootDecayRateAvg: the combined substrate quality effects of all the dead fine root pools ($year^{-1}$).

DeadBranchDecayRateAvg: the combined substrate quality effects of all the dead branch pools ($year^{-1}$).

DeadSapwoodDecayRateAvg: the combined substrate quality effects of all the dead sapwood pools ($year^{-1}$).

DeadHeartwoodDecayRateAvg: the combined substrate quality effects of all the dead heartwood pools ($year^{-1}$).

DeadCRootDecayRateAvg: the combined substrate quality effects of all the dead coarse root pools ($year^{-1}$).

Example of SubQual.dgn file:

SubQual.dgn

Year, DeadFoliageDcayRateAvg, DeadFRootDcayRateAvg, DeadBranchDecayRateAvg, DeadSapwoodDcayRateAvg, DeadHeartwoodDcayRateAvg, DeadCRootDcayRateAvg

```
  1.0    0.900    0.000    0.000    0.000    0.000    0.000
  2.0    0.900    0.900    0.000    0.000    0.000    0.000
  3.0    0.891    0.900    0.000    0.000    0.000    0.000
  4.0    0.893    0.889    0.150    0.100    0.000    0.100
  5.0    0.895    0.888    0.150    0.100    0.020    0.100
  6.0    0.897    0.891    0.150    0.100    0.020    0.100
  7.0    0.898    0.893    0.150    0.100    0.020    0.100
  8.0    0.899    0.894    0.150    0.100    0.020    0.100
  9.0    0.899    0.894    0.150    0.100    0.020    0.100
 10.0    0.899    0.892    0.150    0.100    0.020    0.100
 11.0    0.898    0.890    0.150    0.100    0.020    0.100
 12.0    0.897    0.886    0.150    0.101    0.020    0.100
 13.0    0.896    0.878    0.150    0.102    0.020    0.100
 14.0    0.893    0.867    0.150    0.105    0.020    0.100
 15.0    0.888    0.849    0.150    0.110    0.020    0.100
 16.0    0.879    0.821    0.150    0.117    0.020    0.100
 17.0    0.864    0.780    0.150    0.124    0.020    0.100
 18.0    0.843    0.724    0.150    0.126    0.020    0.100
 19.0    0.828    0.673    0.150    0.123    0.020    0.100
 20.0    0.814    0.631    0.150    0.148    0.020    0.100
 21.0    0.797    0.587    0.150    0.146    0.020    0.100
 22.0    0.787    0.561    0.150    0.144    0.020    0.100
 23.0    0.763    0.526    0.150    0.142    0.020    0.100
 24.0    0.747    0.504    0.150    0.139    0.020    0.100
 25.0    0.710    0.470    0.150    0.136    0.020    0.100
 26.0    0.701    0.458    0.150    0.133    0.020    0.100
 27.0    0.659    0.430    0.150    0.130    0.020    0.100
 28.0    0.644    0.419    0.150    0.128    0.020    0.100
 29.0    0.634    0.411    0.150    0.125    0.020    0.100
 30.0    0.618    0.401    0.150    0.122    0.020    0.100
 31.0    0.611    0.396    0.150    0.120    0.020    0.100
 32.0    0.578    0.382    0.150    0.118    0.020    0.100
 33.0    0.572    0.390    0.150    0.116    0.020    0.100
 34.0    0.524    0.373    0.150    0.115    0.020    0.100
 35.0    0.483    0.359    0.150    0.113    0.020    0.100
 36.0    0.450    0.348    0.150    0.112    0.020    0.100
 37.0    0.423    0.340    0.150    0.111    0.020    0.100
 38.0    0.402    0.333    0.150    0.110    0.021    0.100
 39.0    0.384    0.327    0.150    0.109    0.021    0.100
 40.0    0.369    0.323    0.150    0.108    0.021    0.100
 41.0    0.357    0.319    0.150    0.107    0.021    0.100
 42.0    0.347    0.316    0.150    0.106    0.021    0.100
 43.0    0.338    0.313    0.150    0.106    0.022    0.100
 44.0    0.332    0.311    0.150    0.105    0.022    0.100
 45.0    0.326    0.309    0.150    0.105    0.022    0.100
```

Species.dgn

This file outputs the species of the upper tree layer, the lower tree layer, the height of the upper tree layer (years since planted) and the age of the upper tree layer (m). For each row of the stand the value of these variables is printed on a separate line in the order listed above. If a species is not present in a layer, then NULL is printed. This file is used to check to see if the regeneration of species is consistent with the shading expected from adjacent cells.

Example Species.dgn

Year: 100

```
Abco Psme Abam Pila Abgr Cade Cach Abpr Tshe Abpr
NULL NULL Abam Tshe Tshe Tshe Tshe NULL Tshe NULL
   6   34   23   34   19   34    7   28   17   32
  25   92   64   92   56   92   28   76   51   87

Cach Psme Potr Abpr Psme Abpr Abpr Psme Thpl Tshe
Tshe Abam Abpr Tshe Tshe NULL Tshe Quga Abam NULL
  32   30   27   34   22   34   33   31   22   15
  88   81   73   92   63   92   90   84   61   47

Tshe Acma Abco Abam Tshe Potr Psme Abco Abam Tshe
NULL Abam Tshe Tshe Tshe Abam Abam Tshe Tshe NULL
  11   31   19    9   22   30   29   21   24   18
  38   84   55   32   62   81   79   59   66   54

Alru Thpl Psme Abam Cade Psme Pila Abgr Psme Psme
Psme Abam Arme NULL Tshe Tshe NULL Tshe NULL Alru
  32   21   33   13   32   31   33   14   34   34
  87   60   90   41   87   85   91   45   93   93

Tshe Tshe Tshe Abam Alru Abam Abpr Abgr Abpr Psme
NULL Tshe NULL Abam NULL NULL NULL NULL Tshe Abam
  12   22   11   16   11   19   34   11   33   18
  39   63   38   49   37   55   92   38   91   54

Abam Tshe Abgr Thpl Tshe Psme Abam Psme Abam Abam
NULL NULL NULL Abam Abam NULL Abam Tshe NULL Abco
   8    7   16   19   16   34   24   34   10   23
  30   28   49   56   48   93   66   92   34   65

Psme Psme Psme Abam Abpr Abam Psme Psme Cach Abpr
Tshe Tshe Abam Tshe Abam Abgr Tshe Tshe Tshe Acma
  13   33   23   16   21   15   33   33   32   28
  41   90   65   49   60   46   90   91   87   77

Abpr Abco Abpr Psme Abpr Tshe Abpr Abam Abam Abpr
Tshe Abam Tshe Tshe NULL Abam NULL Abam NULL Tshe
  34   10   32   31   34   21   33   14   20   32
  93   35   88   84   93   59   89   45   57   88

Tshe Alru Tshe Alru Abam Abpr Acma Cade Abam Abpr
Tshe Abam Tshe Abam NULL Abgr NULL Tshe Tshe NULL
  19   34   20   33   15   16    6   33   20   32
  56   92   58   91   47   48   26   89   58   86

Abpr Psme Pila Psme Acma Abgr Psme Abam Tshe Cade
Abam Tshe Tshe NULL Abam NULL Tshe Tshe NULL Tshe
  19   32   33   32   33    8   33   23   19   34
  56   88   89   87   91   31   91   65   55   92
```

Neighbor.dgn

This file contains the upper tree height as well as the fraction of full diffuse, direct, and total radiation out for all the cells in a selected year. The files are output as a matrix of values for each cell (see examples below). The values for diffuse, direct, and total radiation are printed as separate matrices. The value following the heading for the type of radiation reported is the amount recieved when there is no shading.

Example of Neighbor.dgn file:

```
Neighbor.dgn
Year: 500   Slope:    0.00   Aspect: 180.00   Border: same
Solar Azimuth Angle:   99.30     Solar Altitude Angle:   55.01

Diffuse Radiation:    151.68

   103        87       119       176        54       180       180        83        95       154
   120        74        77       131       119       128       100       113       170       178
   163       121       143       129       141       157        65        73       156       181
   111       104       158        52       161       115        67       148       120       177
   140       109       102       145       104        70       133        62       120       163
   106       166       161        61       132        63       109       159        94        67
   182       141        88       147       120        98       154       105        80       177
    78       108       116       144       109       150       133       159       100       182
    59        91       164       100       152       103       164       163        61        91
   126       126       178       166        62       152        87       138       186       178

Direct Radiation:    156.13

   145       145       151       156         0       156       156       103        42       151
   145         0        42       151       151       151       103       145       156       151
   156       145       151       151       151       156        61        42       156       156
   145       145       156         0       156       145        84       151       145       156
   151       103       145       156       145        61       156        84       151       156
   145       156       156        42       145        61       145       156       103        42
   156       151       145       156       145       145       156       145        61       156
   145       103       151       156       145       156       145       156       145       156
     0       103       156       145       151       145       156       156         0       103
   145       151       156       156         0       151       145       151       156       151
```

```
example continued
Total Radiation:    307.81

   248     232     270     332      54     336     336     186     138     305
   265      74     119     282     270     279     203     259     326     329
   319     266     293     280     292     314     126     116     312     337
   256     249     314      52     317     261     151     299     266     333
   290     212     248     302     249     131     289     146     271     319
   251     322     317     103     277     124     254     315     197     109
   338     291     234     303     265     243     310     250     141     333
   223     211     266     300     254     306     278     315     245     338
    59     195     320     245     302     248     320     319      61     194
   271     277     335     322      62     303     232     288     342     328

Tree Height

  24.1    13.1    32.2    56.0     5.1    59.9    59.9    20.7    28.1    45.8
  30.4     6.3    11.8    39.4    40.3    46.4    32.6    35.6    59.9     5.9
  47.7    34.9    44.1    45.2    50.7    59.9    10.0    17.6    59.9    59.9
  31.2    28.1    55.2     4.7    59.9    38.3     6.7    53.1    46.0    59.9
  41.8    32.6    34.6    52.8    30.4    10.0    46.6    10.9    42.3    52.5
  33.3    59.3    59.9     7.9    46.6     6.3    35.6    59.9    26.6    13.1
  59.9    48.8    27.4    52.1    40.8    30.4    59.9    38.6    22.4    59.9
  14.5    29.3    36.8    51.5    35.9    55.0    51.0    59.9    35.3    59.9
   0.0    20.7    59.9    34.6    53.5    34.3    58.0    58.5    14.0    27.4
  33.9    36.5    57.1    54.1     9.1    48.2    24.9    45.6    59.9    53.6
```

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