LANDIS-II Biomass Succession v3.5 Extension User Guide

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1 Introduction

This document describes the **Biomass Succession (v3)** extension for the LANDIS-II model. For information about the LANDIS-II model and its core concepts including succession, see the *LANDIS-II Conceptual Model Description.*

The Biomass Succession Extension generally follows the methods outlined in Scheller and Mladenoff (2004). Biomass Succession (v3) calculates how cohorts reproduce, age, and die. In addition, changes in cohort biomass (g/m^2) are simulated. The Biomass Succession Extension tracks dead biomass over time, divided into two pools: woody and leaf litter.

1.1 What's new in version 3.5

This document describes the current version (3.5) of the extension.

Biomass Succession v3.5 has a modified age-related mortality function, and a revised method for calculating growing space competition.

1.2 What's new in version 3.0

The extension is now compatible with LANDIS-II v6.0. All succession extensions for v6.0 are required to include the initial communities text file and inputs map. Previously these were input in the **Scenario** file. These details are outlined in section 5.

Biomass Succession v3 now includes a growth curve parameter, which determines how quickly ANPP reaches its maximum (see below).

In addition, the three tables for maximum ANPP, maximum aboveground biomass (AGB), and the probability of establishment have been replaced by a single text file which allows temporal updates (as would be used for climate change research) to be defined within the file. See section 3 for further details.

The extension now carries an additional species-ecoregion establishment probability modifier that is accessible to other extensions. The modifier resets to a value of 1.0 after each succession time step. Between succession time steps, disturbance extensions can change the value of the establishment modifier for any species-ecoregion combination. At the successive succession time step, the regular probability of establishment for each species-ecoregion is multiplied by the corresponding establishment modifier, which (if the modifier does not equal 1.0) results in an altered establishment probability for that time step. No additional inputs are required for this new functionality.

1.3 What's new in version 2.2

Two new optional keywords have been added: **CalibrateMode** and **SpinupMortalityFraction**. CalibrateMode simply outputs additional information to the Landis-log file. This can create very large log files. SpinupMortalityFraction adds background mortality during the biomass spin-up phase. This allows a more realistic initial condition whereas previous versions often overestimated initial biomass and underestimated initial dead biomass because there is no disturbance during the spin-up phase.

In addition, a capacity reduction was added to allow the simulation of land use change. This feature is only enabled when Biomass Harvest is used in conjunction with the **PreventEstablish** parameter. In this case, the mean biomass reduction (from Biomass Harvest) is applied to the species x ecoregion maximum biomass. No additional inputs to Biomass Succession v2 are required for this functionality.

1.4 What's new in version 2.1

The initial biomass equation has been changed such that initial biomass is now relative to the maximum possible biomass for each *species*. This change removes problems arising from very large disparities in maximum biomass among species.

In addition, the processing of dead biomass has been improved, eliminating a tendency to overestimate non-woody inputs to the litter layer.

1.5 What's new in version 2.0

The second version of Biomass Succession was created to compensate for some of the weaknesses of the first. Except for the changes listed below, version 2.0 incorporates any relevant bug fixes found in version 1.2.

First and foremost, maximum aboveground biomass (AGB) is now an input parameter. This change was made to accommodate recent data from the literature (Keeling and Phillips 2007) that suggest that the relationship between above ground net primary productivity (ANPP) and AGB is not linear beyond ~10 Mg ha^{-1} yr^{-1}. In addition, separate input for maximum AGB better accommodates shrubs and grasses that have different relationships between ANPP and AGB.

Second, the probability of establishment given light conditions (P_{est} | L) can now range from 0.0 to 1.0. In all previous versions of LANDIS, P|L was either only 0.0 or 1.0. The original parameters are provided in the example input file given with this version. These parameters are perhaps 'hopeful monsters' in that empirical or simulated data to estimate these parameters has not yet been gathered.

Finally, Meentemeyer's decay function (Meentemeyer 1978) is now coded directly into the extension. Percent leaf lignin by species and actual evapotranspiration by ecoregion are now separate input parameters. The goal here was to simplify inputs as this is currently the most common method for calculating leaf decay parameters. If leaf decay is unimportant, the user should provide high values for AET (e.g., 1000).

1.6 Shade Calculation

There are six possible site shade classes ranging from zero (no shade) to 5 (highest shade). Site shade is calculated based on the percentage of biomass present on a site relative to the maximum possible biomass for an ecoregion. The highest percentage allowed is 100%. The maximum possible biomass for an ecoregion is the maximum of all species maximum biomass (from the list of maximum biomass by species and ecoregion provided by the user).

User Tip: *If a species cannot occur in an ecoregion (e.g., establishment probability = 0.0), you should set the species maximum biomass to 0 for that species and ecoregion. This will ensure that the species doesn't influence the shade calculation for that ecoregion.*

A site will remain shade class 0 until the minimum percent biomass for shade class 1 is reached. Likewise, the site will assign shade class 1 until the percentage for shade class 2 is reached.

For example: If the maximum possible biomass for a site is 1000 (units are arbitrary) and the actual total site biomass is 550, the resulting percentage is 55%. The function for calculating shade progresses from lowest to highest shade class. If the user lists shade class 3 = 45% and shade class 4 = 60%, then the shade class assigned to the site will be 3.

User Tip: *If you want to limit the highest shade class assigned, as may be the case if an ecoregion never achieves 'closed canopy' conditions, you can assign a 100% value to a lower shade class. For example, if you want to limit assigned shade classes to 4 or less, then set shade class 4 = 100% and shade class 5 = 100%. When shade is being calculated, shade class 4 will meet its requirement before shade class 5. The function that calculates shade class will therefore assign shade class 4 to the site.*

Note: *The calculation of shade class is independent of any growth calculations***.**

1.7 Cohort Reproduction – Disturbance Interactions

Recall that every disturbance will trigger succession at each site at the time step that the disturbance(s) occur. In succession, there is a hierarchy of reproduction options following a disturbance. The goal of this design was to give reproductive precedence to species with propagules available on site.

If planting (currently possible only through a Harvest extension) is triggered for one or more species, then no other reproduction will occur. Planting is given highest precedence as we assume that a viable cohort is generated. However, the probability of establishment must be greater than zero.

If serotiny (only possible immediately following a fire) is triggered for one or more species, then neither resprouting nor seeding will occur. Serotiny is given precedence over resprouting as it typically has a higher threshold for success than resprouting. This slightly favors serotinous species when mixed with species able to resprout following a fire.

If resprouting (which can be induced by many disturbance types) is triggered, then seeding will not occur.

Finally, if neither planting, serotiny, nor resprouting occurred, seeding dispersal into a sight will occur.

1.8 Cohort Reproduction – Initial Biomass

Cohort reproduction is the establishment of a cohort, aged 1 year and the calculation of its initial biomass.

$$InitialBiomass = 0.025 \times B_{MAX-SPP} \times Exp\left(-1.6 \times B_{SUM} / B_{MAX-ECOREGION}\right)$$

where $B_{MAX\text{-}SPP}$ is the maximum biomass possible for the *species;* $B_{MAX\text{-}ECOREGION}$ is the maximum biomass possible for the *ecoregion*; and B_{SUM} is the current total biomass for the site (not including other new cohorts). Initial biomass must be ≥ 1 (g / m^2); if < 1, initial biomass is set equal to 1.

Note: this initial cohort will be grouped ('binned') appropriately into a larger cohort (e.g., 1 – 10) at the next successional time step.

1.9 Cohort Growth and Ageing

Cohort net growth is based on the principles outlined in Scheller and Mladenoff (2004). Cohort net growth takes into consideration the age of the cohort, species, ecoregion, and competition. Cohort net growth is gross growth minus development-related mortality. **Cohort growth occurs at an annual time step, regardless of the overall extension time step.**

Competition and age reduce the maximum cohort biomass (B_{MAX}). Competition occurs when a stand contains more than one cohort. The potential biomass (B_{POT}) represents the available 'growing space', minus space already occupied by other species age cohorts. There are two alternative calculations for B_{POT}; the maximum of the two is used in subsequent calculations. The first estimates potential discounting space occupied by all cohorts:

$$B_{POTij} = \max\left[0, B_{MAXi} - \sum_{1}^{i}\sum_{1}^{j} B_{ij}\right] \tag{1}$$

where *i* is species, *j* is age cohort. B_{ij} is the biomass for a single cohort. (This equation is a correction to the original found in Scheller and Mladenoff, 2004.) The second formulation was added to allow any recent non-disturbance mortality (i.e., from cohort senescence) to contribute to growing space. The purpose of the second formulation is to allow young cohorts some growing space as may be generated by within-cell gap-phase dynamics. For example, individual trees within an older cohort are dying due to old-age. Those gaps create growing space for younger cohorts.

$$B_{POTij} = \mathrm{Pr}\,evYearMortality \tag{2}$$

where *PrevYearMortality* is all non-disturbance related mortality at the site during the previous year.

Note: *In the biomass succession extension, growth operates at an annual time step, regardless of the overall extension time step. Therefore,* PrevYearMortality *is literally from the previous year, not the previous extension time step.*

Next, the effect of development and competition is calculated. This is a limit to productivity due to the biomass of a cohort relative to its potential, i.e., a very young or small cohort is not as productive as a large, mature cohort:

$$DevelopmentLimit = e^{1} \times B_{AP}^{\;GC} \times e^{-\left(B_{AP}^{\;GC}\right)} \tag{3}$$

where *GC* is the growth curve shape parameter, and B_{AP} is the biomass-weighted average ratio of cohort biomass (B_{ij}) to cohort potential (B_{POTij}) across all cohorts on a site:

$$B_{AP} = \frac{\sum_{1}^{i}\sum_{1}^{j}\left[\frac{B_{ij}}{B_{POTij}} \times B_{ij}\right]}{\sum_{1}^{i}\sum_{1}^{j}\left[B_{ij}\right]} \tag{4}$$

As productivity declines with age, the decline in maximum ANPP is a function of age relative to longevity:

$$ANPP_{DECij} = ANPP_{MAXi} \times \frac{1}{1+\left[\frac{1}{X0_{i}}-1\right]\times e^{-\left(MortR_{i}\times AGE_{ij}\right)}} \tag{5}$$

where *X0* and *mortR* are parameters derived from the mortality curve input parameters:

$$X0_{i} = 0.5e^{-1} \times \frac{e^{\left[\ln\left(\frac{0.05^{2}}{0.95^{2}}\right)\times\left(\frac{Longevity_{i}\times AgeMort_{i}}{-1\times Longevity_{i}\times AgeMort_{i}-Longevity_{i}}\right)\right]}}{0.5e^{-1}\times e^{\left[\ln\left(\frac{0.05^{2}}{0.95^{2}}\right)\times\left(\frac{Longevity_{i}\times AgeMort_{i}}{-1\times Longevity_{i}\times AgeMort_{i}-Longevity_{i}}\right)\right]}+0.95} \tag{6}$$

$$MortR_{i} = \frac{-\ln\left(-0.95\times\frac{X0_{i}}{-0.5e^{-1}+0.5e^{-1}\times X0}\right)}{Longevity_{i}\times AgeMort_{i}} \tag{7}$$

where $AgeMort_i$ is the proportion of longevity at which age-related mortality begins.

Finally, the actual biomass for a cohort is calculated:

$$ANPP_{ACTij} = \left(ANPP_{MAXi} - ANPP_{DECij} \right) \times DevelopmentLimit \tag{8}$$

Cohort net biomass change is net growth minus mortality. Mortality is caused by senescence (below) and 'development'. Development mortality (M_{BIOij}) is the ongoing loss of individual trees and branches. It does not include leaf litter. Development mortality is low when a cohort is young or small, accelerates during the stem-exclusion phase (between young and mature ages), and plateaus at maturity. It is also constrained by actual ANPP to ensure that is appropriate relative to a cohort's growth:

$$M_{BIOij} = ANPP_{ACTji} \times \frac{2 \times B_{AP}}{1 + B_{AP}} \tag{9}$$

Cohort ageing is simply the addition of the time step to each existing cohort.

1.10 Cohort Senescence and Mortality

As a cohort nears its longevity age, there will be an increase in the loss of biomass. This is called **age-related mortality**, and the age at which this mortality begins to be a factor is species-specific and controlled by the user with the *AgeMort* parameter and the resulting parameters *X0* and *MortR* (see equations 6 and 7 above).

$$PM_{AGEij} = \frac{1}{1 + \left(\frac{1}{X0_i} - 1 \right) \times e^{-MortR_i \times AGE_{ij}}} \tag{10}$$

where PM_{AGE} is the proportion of biomass to be removed annually. The biomass will decline to near zero at the maximum life span. Cohorts are **not** randomly killed as in Age-Only Succession. To prevent biomass from being removed too quickly and causing premature collapse, the actual biomass removed due to age mortality is regulated by a second user input, *PropMort*, which represebts the proportion of biomass to be removed annually at the species longevity:

$$M_{AGEij} = B_{ij} \times PM_{AGEij} \times PropMort \tag{11}$$

If a cohort exceeds the longevity for that species, then the cohort dies.

1.11 Dead Biomass Decay

When a cohort dies and is not consumed by a mortality agent (e.g., fire or harvest), its biomass is added to one or both of the two dead biomass pools: **woody** and **leaf**.

There is a mean decay rate for each pool at each site, determined by using a weighted average (weighted by mass) of the new dead material decay rate (user-determined) and the existing pool decay rate.

Disturbances can alter the dead biomass pools. They can add dead biomass (e.g., wind) and/or remove dead biomass (e.g., fire will add some woody dead biomass and remove all leaf dead biomass).

1.12 Initializing Biomass

At the beginning of a scenario, the initial communities begin with appropriate living and dead biomass values estimated for each site. **However, the user does not supply the initial biomass estimates.** Rather, the Biomass Succession extension iterates the number of time steps equal to the maximum cohort age for each site. Beginning at time (t - oldest cohort age), cohorts are added at each time step corresponding to the time when the existing cohorts were established. Thus, each cohort undergoes growth and mortality for the number of years equal to its current age, and its initial biomass value reflects competition among cohorts. Note: this is a computationally intensive process that may require significant time for complex initial landscapes.

This biomass initialization can now account for disturbances that would likely happen prior to initialization. The optional keyword **SpinUpMortalityFraction** allows additional mortality which is applied equally to all cohorts. The additional spin-up mortality is added to **age-related mortality** (M_{AGEj}). If the **SpinUpMortalityFraction** is not used, the extension will tend to overestimates initial live biomass and underestimates initial dead biomass quantities.

1.13 Interactions with Age-Only Disturbances

Biomass Succession was written to allow disturbances that operate on age-only cohorts to interact with the two dead biomass pools. For example, a User is able to run the Base Fire or Base Wind extensions with Biomass Succession. Although neither disturbance extension is 'biomass aware', a simple interface was created that enables the biomass of cohorts killed by the disturbance to be allocated to dead biomass pools. The interface allows a User to indicate a) whether and how much non-woody or woody **live biomass** is transferred to their respective dead pools by a disturbance type and b) whether and how much of the non-woody or woody **dead biomass pools** are removed by a disturbance type.

For example, if a fire kills a cohort, we would expect that all of its non-woody and some of the woody biomass to be volatilized immediately and this biomass would not enter a dead biomass pool. In addition, we would expect some of the existing woody dead biomass pool to be volatilized during a fire and perhaps all of the existing non-woody biomass pool (i.e., the forest floor) to be volatilized.

This interface does not allow dynamic changes in the transfer rates into and out of the dead pools. Rather, the interface was designed to allow existing age-cohort disturbances to be used with Biomass Succession.

The interface is specified in a separate LandisData parameter file: "Age-only Disturbances - Biomass Parameters". See Chapter 4.

1.14 Dynamic Inputs for Climate Change or Other

Only three sets of parameters can be updated: maximum ANPP, maximum AGB, and the probability of establishment. By allowing the parameters to be updated, the effects of climate change on succession (or any temporal dynamics related to succession) can be simulated. The inputs can be updated at any time step.

1.15 References

Keeling, H. C. and Phillips, O. L. The global relationship between forest productivity and biomass. Global Ecology and Biogeography. 2007; 16:618-631.

Meentemeyer, V. Macroclimate and lignin control rates of litter decomposition rates. Ecology. 1978; 59(3):465-472.

Scheller, R. M. and Mladenoff, D. J. A forest growth and biomass module for a landscape simulation model, LANDIS: Design, validation, and application. Ecological Modelling. 2004; 180(1):211-229.

1.16 Acknowledgments

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2 Succession Input File

Nearly all the input parameters for this extension are specified in one main input file. This text file must comply with the general format requirements described in section 3.1 *Text Input Files* in the *LANDIS-II Model User Guide*.

2.1 LandisData

This parameter's value must be `"Biomass Succession"`.

2.2 Timestep

This parameter is the timestep of the extension. Value: integer > 0. Units: years.

2.3 SeedingAlgorithm

This parameter is the seeding algorithm to be used. Valid values are `"WardSeedDispersal"`, `"NoDispersal"` or `"UniversalDispersal"`. The algorithms are described in section 4.5.1 *Seeding* of the *LANDIS-II Conceptual Model Description*.

2.4 InitialCommunities

This parameter is the file with the definitions of the initial communities at the active sites on the landscape (see chapter 4).

2.5 InitialCommunitiesMap

This parameter is the input map indicating the initial communities at the active sites on the landscape. Each cell value for an active site on the landscape must be one of the map codes listed in the initial communities input file (see chapter 4).

2.6 CalibrateMode

An optional variable, CalibrateMode determines whether additional log file data is activated. Input = ‘yes’ or ‘no’ or Y or N.

2.7 SpinUpMortalityFraction

This parameter determines how much additional mortality is active during the biomass spin-up phase. This is used to estimate the background level of disturbance and to prevent initial overestimates of live biomass. Input is the fraction of cohort biomass that is added to age-related mortality. Expected value 0.0 – 0.5.

2.8 MinRelativeBiomass Table

This table contains the minimum relative biomass for shade classes 1 - 5.

2.8.1 First Row – Ecoregions

The first row in the table is a list of all the active ecoregions defined in the ecoregions input file (see chapter 6 in the *LANDIS-II Model User Guide*. The ecoregions can appear in any order; they do not need to appear in the same order as in the ecoregions input file.

2.8.2 Other Rows

There are 5 other rows in the table, one row for each shade class.

2.8.3 Shade Class

This column contains shade class values: $1 \leq$ integer ≤ 5. The shade classes must be in increasing order: class 1 first and ending with class 5. Shade class 5 represents the most shade. A site will be shade class 0 (no shade) until the minimum relative biomass for shade class 1 is reached.

2.8.4 Minimum Biomass Percentage per Ecoregion

Each ecoregion listed in the table's first row (see section 2.8.1) must have a separate column of minimum biomass by shade class. The percentages represent the lower threshold of biomass on a site relative to the ecoregion's maximum possible biomass (for any species) for the site to enter the shade class indicated in column 1. Sites with less than the lowest threshold value will be assigned to shade class 0 (full sunlight). The maximum biomass for an ecoregion is the maximum growth rate (for any species) multiplied by 30 (equation 2, Scheller and Mladenoff 2004). Value: $0.0 \leq$ decimal number ≤ 100.0. Units: percent.

2.9 SufficientLight Table

2.9.1 Species Shade Tolerance Class

This column contains shade class values: 1 ≤ integer ≤ 5. The shade classes must be in increasing order: class 1 first and ending with class 5. Shade class 5 represents the most shade tolerant.

2.9.2 Probability of Establishment, given light conditions

Each possible site-level light condition (0 – 5) has an associated probability for each species shade tolerance class (1 – 5). Value: 0.0 ≤ decimal number ≤ 1.0.

2.10SpeciesParameters Table

This table contains species' biomass parameters. Each row in the table has the parameters for one species. Every active species must have an entry.

2.10.1 Species

The species must be defined in the species input file (see chapter 5 in the *LANDIS-II Model User Guide*). Species may appear in any order.

2.10.2 Leaf Longevity

This parameter is the average longevity of a leaf or needle. Value: 1.0 ≤ decimal number ≤ 10.0. Units: years.

2.10.3 Woody Decay Rate

This parameter, *k*, defines the rate (e^{-k}) at which the species' dead wood decomposes in the ecoregion. Value: 0.0 ≤ number ≤ 1.0. Unitless.

Decomposition is calculated according to Equation 7 in Scheller and Mladenoff (2004) such that Dead Biomass (t+1) = Dead Biomass(t)*e^-*k*. The time step in the equation is1 year, and the Biomass Extension correctly applies the formula regardless of the extension time step.

2.10.4 Leaf Lignin

The percent leaf lignin per species. Value: 0.0 ≤ decimal number ≤ 1.0.

2.11 EcoregionParameters Table

2.11.1 First Column – Ecoregions

The first column in the table is a list of one or more active ecoregions defined in the ecoregions input file (see chapter 6 in the *LANDIS-II Model User Guide*). The ecoregions can appear in any order; they do not need to appear in the same order as in the ecoregions input file.

2.11.2 Actual Evapotranspiration (AET)

Used to determine decay rates for leaf decomposition. Value: $0 \leq$ integer number $\leq 10{,}000$ (Note: the value is typically < 1000). Units: mm.

2.12 DynamicInputFile

This parameter indicates a text file containing the input data for maximum ANPP, maximum AGB, and probability of establishment. See chapter 3 below for further information.

2.13 AgeOnlyDisturbances:BiomassParameters

This optional file parameter is the path of a text file with the biomass parameters to be used with age-cohort disturbances (e.g., Base Wind, Base Fire, Base BDA). The format of that file is described in chapter 3.

3 Input File – Dynamic Inputs

This **required** input file contains a table of biomass parameters used both with and without climate change. The file reads in necessary data and allows these data to be updated at any annual time step. This could allow the user to test climate change scenarios, for example, or to test the effects of variable ANPP over time.

This text file must comply with the general format requirements described in section 3.1 *Text Input Files* in the *LANDIS-II Model User Guide*.

3.1 LandisData

This parameter's value must be `"Dynamic Input Data"`.

3.2 Dynamic Input Data Table

Besides the LandisData parameter, the file should only contain a space or tab delimited table containing the dynamic inputs.

3.2.1 Column 1: Year

This column is the year that the parameters change. Value: integer.

A year expression represents the time step. **Values for time step zero are required.**

3.2.2 Column 2: Ecoregions

The second column in the table is a list of one or more active ecoregions defined in the ecoregions input file (see chapter 6 in the *LANDIS-II Model User Guide*). The ecoregions can appear in any order; they do not need to appear in the same order as in the ecoregions input file.

Every active ecoregion that is not listed will have default parameter values assigned to all the species (given below).

3.2.3 Column 3: Species

The third column in the table is the list of species for each ecoregion. The species can be listed in any order in a table. A species can be omitted. If so, it will be assigned the default parameter value for all active ecoregions.

3.2.4 Column 4: Establishment Probabilities

This parameter is the probability that the species establishes in the ecoregion. Value: $0.0 \leq$ decimal number ≤ 1.0. Default value: 0.0

3.2.5 Column 5: Maximum ANPP

This parameter is the maximum possible aboveground net primary productivity (ANPP) for the species in the ecoregion. Value: $0 \leq$ integer $\leq 100{,}000$. Units:

New: The units must be **g biomass / m^2 / year**. Default value: 0

3.2.6 Column 6: Maximum Biomass

This parameter defines the maximum allowable aboveground biomass (AGB) for the species in the ecoregion. Value: $0 \leq$ integer. The units must be **g biomass / m^2**. Default value: 0

3.2.7 Column 7: Growth Curve – Shape Parameter

This parameter determines how quickly ANPP reaches its maximum. Value: $0.0 \leq$ decimal number ≤ 1.0. A value of 1.0 is the slowest increase in ANPP and reflects the assumptions of all previous Biomass Succession extensions. As the value become smaller, ANPP will reach maximum at a faster rate.

3.2.8 Column 8: Age of Mortality (AgeMort)

This parameter determines at what proportion of longevity age-related mortality removes 5% of the cohort biomass. The logistic mortality function increases with age and reaches 95% removal at longevity. The AgeMort parameter determines how quickly age-related mortality increases with age. Value: $0.0 \leq$ decimal number ≤ 1.0.

3.2.9 Column 9: Maximum Proportion Mortality (PropMort)

This parameter determines the maximum proportion of cohort biomass removed annually due to age-related mortality. This parameter, when less than 1.0, regulates the age-related mortality to prevent mortality removing nearly all biomass prior to longevity. A very low value for this parameter can cause a large amount of biomass to remain at longevity, resulting in a dramatic crash in biomass with the death of the cohort. The Value: $0.0 \leq$ decimal number ≤ 1.0.

4 Input File – Age-only Disturbances

This optional auxiliary input file contains the biomass parameters used when age-only disturbances kill biomass cohorts (see section 2.12 *DynamicInputFile*

This parameter indicates a text file containing the input data for maximum ANPP, maximum AGB, and probability of establishment. See chapter 3 below for further information.

AgeOnlyDisturbances:BiomassParameters). This text file must comply with the general format requirements described in section 3.1 *Text Input Files* in the *LANDIS-II Model User Guide*.

4.1 LandisData

This parameter's value must be `"Age-only Disturbances - Biomass Parameters"`.

4.2 CohortBiomassReductions Table

This table describes how much a dead cohort's biomass is reduced by a disturbance before the biomass is added to the corresponding dead pool. Each row describes the reductions associated with a particular type of disturbance.

4.2.1 Disturbance

This text parameter is the type of the disturbance. The disturbance name must be consistent with the LandisData name given in the disturbance extension. The keyword `"(default)"` specifies the reductions for all disturbance types not listed in the table. The row with the default reductions must be present in the table.

4.2.2 Woody

This parameter is the percentage by which the disturbance reduces a dead cohort's woody biomass. Value: 0% ≤ integer percentage ≤ 100%. The biomass remaining after the reduction is added to the dead woody pool at the site where the cohort was killed.

4.2.3 Non-Woody

This parameter is the percentage by which the disturbance reduces a dead cohort's non-woody biomass. Value: 0% ≤ integer percentage ≤

100%. The biomass remaining after the reduction is added to the dead non-woody pool at the site where the cohort was killed.

4.3 DeadPoolReductions Table

This table describes how much a disturbance reduces the dead biomass pools at the sites it disturbs. Each row describes the reductions associated with a particular type of disturbance.

4.3.1 Disturbance

This text parameter is the type of the disturbance. The disturbance name must be consistent with the LandisData name given in the disturbance extension. The keyword "`(default)`" specifies the reductions for all disturbance types not listed in the table. The row with the default reductions must be present in the table.

4.3.2 Woody

This parameter is the percentage by which the disturbance reduces a site's dead woody biomass. Value: 0% ≤ integer percentage ≤ 100%.

4.3.3 Non-Woody

This parameter is the percentage by which the disturbance reduces a site's dead non-woody biomass. Value: 0% ≤ integer percentage ≤ 100%.

5 Initial Communities Input File

This file contains the definitions of the initial community classes. Each active site on the landscape is assigned to an initial community class. The class specifies the tree species that are present along with the particular age classes that are present for each of those species.

5.1 Example File

```
LandisData   "Initial Communities"

>>Old jackpine oak
MapCode  7
   acerrubr 30
   pinubank 80 90
   pinuresi 110 140
   querelli 40 120 240

>> young jackpine oak
MapCode  0
   pinubank 30 50
   querelli 10 40 70

>> young aspen
MapCode 2
   poputrem 10 20

>> old maple hardwoods
MapCode 55
   abiebals 10 60 120
   acerrubr 90 120
   acersacc 20 50 150 200
   betualle 40 140 200
   fraxamer 10 100 130 180
   piceglau 180
   querrubr 100 160 180
   thujocci 200 240 260
   tiliamer 20 80 110 150
   tsugcana 30 80 120 220 320 340

>> old pine - spruce - fir
MapCode 6
   abiebals 10 50 80
   piceglau 100 140 180 200 220
   pinuresi 140 160 180
   pinustro 200 280 350
```

5.2 LandisData

This parameter's value must be `"Initial Communities"`.

5.3 Initial Community Class Definitions

Each class has an associated map code and a list of species present at sites in the class.

5.3.1 MapCode

This parameter is the code used for the class in the input map (see section 2.5). Value: $0 \le$ integer $\le 65{,}535$. Each class' map code must be unique. Map codes do not have to appear in any order, and do not need to be consecutive.

5.3.2 Species Present

A list of species present at the class' sites comes after the map code. Each species is listed on a separate data line.

```
species  age  age  age  ...
```

The species name comes first, followed by one or more ages. The name and ages are separated by whitespace. An age is an integer and must be between 1 and the species' Longevity parameter. The ages do not have to appear in any order.

```
acersacc  10  5  21  60  100
```

The list may be empty, which will result in the sites in the class being initialized with no species cohorts.

5.3.3 Grouping Species Ages into Cohorts

The list of ages for each species is grouped into cohorts based on the succession extension's timestep. This timestep determines the size of each cohort. For example, if the timestep is 20, then the cohorts are ages 1 to 20, 21 to 40, 41 to 60, etc.

Suppose an initial community class has this species in its list:

```
acersacc  10  25  30  40  183  200
```

If the succession timestep is 10, then the cohorts for this species initially at each site in this class will be:

```
acersacc  10  20  30  40  190  200
```

If the succession timestep is 20, then the cohorts for this species initially at each site in this class will be:

```
acersacc  20  40  200
```

6 Example Inputs

6.1 Main Parameter File

```
LandisData  "Biomass Succession"

Timestep  10

SeedingAlgorithm  WardSeedDispersal
>> Also NoDispersal or UniversalDispersal

 InitialCommunities      "./initial-communities.txt"
 InitialCommunitiesMap   "initial communities.gis"

CalibrateMode no  << optional parameter

SpinupMortalityFraction 0.001  << optional parameter

>> *********************
   MinRelativeBiomass

>> Shade
>> Class     Ecoregions
>> -----     ------------
             eco1    eco2

     1       25%     20%
     2       35%     30%
     3       45%     40%
     4       60%     50%
     5       95%     80%

>> ***************************
SufficientLight
>> Spp Shade   Probability
>> Class       by Actual Shade
>> ----------  --------------------
>>             0     1     2     3     4     5
   1           1.0   0.0   0.0   0.0   0.0   0.0
   2           1.0   1.0   0.0   0.0   0.0   0.0
   3           1.0   1.0   1.0   0.0   0.0   0.0
   4           1.0   1.0   1.0   1.0   0.0   0.0
   5           0.0   0.0   1.0   1.0   1.0   1.0

>> **************************************************
SpeciesParameters

>> Species  Leaf      Woody      Leaf
>>          Longevity Decay Rate Lignin%
```

```
>> -------- --------- ----------  ------
   abiebals 4.0       0.071      0.2
   acerrubr 1.0       0.096      0.1
   acersacc 1.0       0.096      0.1
   betualle 1.0       0.096      0.1

>> ***************************
EcoregionParameters
>>       AET
>>       mm
eco1     600
eco2     600

DynamicInputFile     biomass-succession-dynamic-
   inputs.txt
AgeOnlyDisturbances:BiomassParameters  bio/AODist.txt
```

6.2 Age-only Disturbances

```
LandisData  "Age-only Disturbances - Biomass Parameters"


CohortBiomassReductions

>> Disturbance   Woody   Non-Woody
>> -----------   -----   ---------
    fire          33%       100%
    wind           0%         0%
    harvest       85%         0%
    (default)     15%         0%


DeadPoolReductions

>> Disturbance   Woody   Non-Woody
>> -----------   -----   ---------
    fire           8%       100%
    (default)      0%         0%
```

6.3 Dynamic Inputs File

```
LandisData  "Dynamic Input Data"

>>                 Prob Max  Max Age  Growth Prop
>> Year Ecoreg Spp Est  ANPP Bio Mort Shape  Mort
>> ---- ------ --- ---  ---- --- ---- ------ ----
0 eco1  abiebals   0.9   886   26000  0.65  0.7  0.14
0 eco1  acerrubr   1.0   1175  26000  0.68  1.0  0.30
0 eco1  acersacc   0.82  1106  26000  0.60  0.8  0.20
0 eco1  betualle   0.64  1202  26000  0.72  0.9  0.10
0 eco1  betupapy   1.0   1202  26000  0.72  1.0  0.20
0 eco1  fraxamer   0.18  1202  26000  0.62  1.0  0.20
```

```
0 eco1  piceglau   0.58  969   26000  0.72  1.0  0.20
0 eco1  pinubank   1.0   1130  26000  0.72  1.0  0.20
0 eco1  pinuresi   0.56  1017  26000  0.72  1.0  0.20
0 eco1  pinustro   0.72  1090  26000  0.72  1.0  0.20
0 eco1  poputrem   1.0   1078  26000  0.72  1.0  0.20
0 eco1  querelli   0.96  1096  26000  0.72  1.0  0.20
0 eco1  querrubr   0.66  1017  26000  0.72  1.0  0.20
0 eco1  thujocci   0.76  1090  26000  0.72  1.0  0.20
0 eco1  tiliamer   0.54  1078  26000  0.72  1.0  0.20
0 eco1  tsugcana   0.22  1096  26000  0.72  1.0  0.20
0 eco2  abiebals   0.05    801   26000  0.65  0.7  0.14
0 eco2  acerrubr   0.6     1058  26000  0.68  1.0  0.30
0 eco2  acersacc   0.3     1003  26000  0.60  0.8  0.20
0 eco2  betualle   0.24  1052  26000  0.72  0.9  0.10
0 eco2  betupapy   0.75  1052  26000  0.72  1.0  0.20
0 eco2  fraxamer   0.1     1052  26000  0.62  1.0  0.20
0 eco2  piceglau   0.5     875   26000  0.72  1.0  0.20
0 eco2  pinubank   0.8     1015  26000  0.72  1.0  0.20
0 eco2  pinuresi   0.78  916   26000  0.72  1.0  0.20
0 eco2  pinustro   0.70  980   26000  0.72  1.0  0.20
0 eco2  poputrem   0.8     968   26000  0.72  1.0  0.20
0 eco2  querelli   0.71  984   26000  0.72  1.0  0.20
0 eco2  querrubr   0.43  916   26000  0.72  1.0  0.20
0 eco2  thujocci   0.002 980   26000  0.72  1.0  0.20
0 eco2  tiliamer   0.06  968   26000  0.72  1.0  0.20
0 eco2  tsugcana   0.01  984   26000  0.72  1.0  0.20
```