LANDIS-II Century Succession v3.0 Extension User Guide

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1 Introduction

This document describes the **Century Succession** 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 Century Succession Extension is a hybrid between the Century soil model (Parton et al. 1993, Schimel et al. 1994, Parton et al. 1994, Pan et al. 1998) and the LANDIS-II Biomass Succession extension (Scheller and Mladenoff 2004). Century Succession calculates how cohorts reproduce, age, and die. In addition, changes in cohort biomass (kg/ha) are simulated (Scheller et al. 2011). Dead biomass is tracked over time, divided into four pools: surface wood, soil wood (dead coarse roots), surface litter (dead leaves), and soil litter (dead fine roots). In addition, three principle soil pools: fast (Soil Organic Matter 1), slow (SOM2), and passive (SOM3) are simulated.

For a schematic drawing of the CENTURY extension, see Scheller et al 2011. For detailed information about Century and Century inputs, see:
http://www.nrel.colostate.edu/projects/century/manual4/man96.html

1.1 What's New in Version 3.0

In this version of CENTURY, we made major improvements to **nitrogen cycling**, made minor changes to **belowground productivity**, **probability of establishment**, and added an **output file** that is generated when CENTURY is run in calibrate mode.

1.1.1 Nitrogen cycling

Nitrogen cycling in previous versions of Century Succession focused primarily on how N regulates C cycling, rather than describing N dynamics, per se.

In version 3.0, total nitrogen, (NH_4^+, NO_3^-, and organic N), is now fully integrated throughout the extension with all the major inputs (deposition, N-fixation, insect frass), outputs (leaching and volatilization) and fluxes (resorption, litterfall, uptake, decomposition) simulated within the extension. This allows users to track C and N cycling in their landscape and better understand the relative importance of N in regulating productivity.

Specifically, we added N resorption, the amount of N withdrawn from the leaves just prior to senescence. Retranslocation is a significant source of N uptake in the spring and can be 10-80% of N uptake depending on species, site and the time since disturbance (Killingbeck 1996, Covelo et al. 2008). Retranslocation for each cohort is calculated in August of each year as the difference between leaf and litter N, and is used the following spring to satisfy the cohorts' early demand for N. After the resorptive pool is depleted, the cohort satisfies its need for N by withdrawing N from the soil (i.e. mineral N).

We also added insect frass to the C and N budget. Most large insect outbreaks occur in the summer before retranslocation occurs, causing a significant decline in the ability of trees to resorb N and potentially decreasing growth the following spring (Lovett et al. 2002). The addition of C and N in frass can cause changes in decomposition rates, which may affect long-term nutrient availability and productivity. In the extension, defoliation events trigger deposition of frass C and N deposition, the relative amount of which is a function of the amount of leaf biomass removed during defoliation. Since C/N ratio of frass (C/N =23 from Lovett and Ruesink, 1995) may differ from litterfall, frass can also cause changes in the decomposition rates of the soil pools that can affect long-term carbon cycling and productivity.

We added N leaching which is a function of soil texture, the amount of available mineral N and the relative rates of base and storm flow. The calculations are based on the original CENTURY model by Parton et al. (1983), though modified so that only NO_3^- (and not total N) is leached from soils. The direct loss of mineral N to the atmosphere – not dependent upon fire as an agent - was modified so that the relative amount can vary with different ecosystems within the landscape. The relative amount of N loss through ammonia volatilization and denitrification is now an input parameter for each ecoregion. This is particularly useful when the landscape includes both uplands and wetlands, since wetlands have a much higher denitrification rates than uplands (Seitzinger et al. 2006). Overall, ammonia volatilization is relatively low (<0.1 g m-2 y-1) from unfertilized forest ecosystems (Schlesinger and Hartley 1992), but denitrification rates can be significant, especially in forested wetlands (0.8 g m^{-2} y^{-1}, (Seitzinger et al. 2006).

We modified how N limits aboveground productivity, switching from a categorical (i.e. N tolerance) to a more process-based approach.

When N is limiting, mineral N is allocated between cohorts based on their biomass (i.e. coarse root biomass). This value is divided by the N demand for each cohort (amount of N needed for growth) to get a relative index (0-1) of how much N is limiting growth for that cohort.

N limitation = N allocation / N demand equation 1

1.1.2 Decay Rates

We added input parameters for the decay rates of the fast-cycling soil pool so the user can better regulate the respiration and N mineralization rates of the SOM1surf and SOM1soil pools. The decay constants of all three soil pools (fast, slow and passive) can now be adjusted to ensure that the relative decomposition rates between pools are realistic and reflect the expected annual changes in each pool.

1.1.3 Belowground Productivity

We modified the relationship between **belowground** and aboveground **productivity**, based on new studies (Albaugh et al. 2006, Park et al. 2008). We increased belowground productivity, such that fine root biomass is now 75% of leaf biomass (was 70% in v2) and coarse root biomass is 50% (rather than 30%) of wood biomass.

1.1.4 Probability of Establishment

We added an input parameter that adjusts the **probability of establishment** based on the time step you specify in CENTURY. This allows users to account for differences in establishment depending on the succession timestep. The expectation is that shorter time steps will have smaller P_{EST}. For example, if you were operating at a 5-year time step and you decided to step it down to a 1-year time step, the adjustment factor of 0.2 should be applied to arrive at equivalent P_{EST}.

1.1.5 Calibrate Output File

We also added a new **output file** that is generated when CENTURY is run in calibrate mode. This output file allows the user to (among other things) determine what is limiting growth of each cohort at each time step.

1.1.6 Harvest Reduction Parameters

We added a new **optional** parameter table that can be used in conjunction with the Leaf Biomass Harvest extension (see “LANDIS-II Leaf Biomass Harvest v2.0 User Guide”). This table indicates the proportion of dead wood and leaf biomass that should be removed as a function of a specific harvest activity. The dead biomass includes cohorts killed from the harvest activity and dead biomass (e.g., coarse woody debris, leaf litter) already present in the forest. **If this table is not used, the harvested cohorts will be follow the parameters in the age-only-disturbance file (see below).** This table may be used if, for example, after a harvest event, a controlled burn would be applied to a stand to remove a proportion of leaf litter and coarse woody debris. *If the table is used be sure to remove harvesting from the age-only-disturbance file.*

1.2 What's New in Version 2.0

Century Succession 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 below. Internal Time Steps

Although the Century Succession is limited to annual or multiple-year time steps, **cohort growth and soil decomposition operate at a monthly time step**. Both growth and decomposition reflect monthly climate and monthly climate is a required input.

Because most disturbances occur in the summer months, the monthly cycle proceeds from July to June. Therefore, **disturbances and reproduction both occur between June and July**.

1.3 Cohort Reproduction – Probability of Establishment

The probability of establishment (P_{EST}) is now internally calculated at an annual time step and is dependent upon input weather data. Although calculated annually, establishment can only occur following a disturbance or at a succession time step. P_{EST} is based on the minimum of three limiting factors: 1) Growing Degree Days, 2) drought tolerance, 3) minimum January temperature. These represent **ecoregion-scale** limits to species establishment in that the requisite parameters vary by ecoregion. Available light is calculated as in Biomass Succession (v2) and is included as a part of the **site scale** limits to establishment.

Reproduction first checks the site-scale limits to reproduction. If this test is passed, ecoregion-scale limits are checked next. If successful, the site and landscape are searched for propagules as in all previous succession extensions.

1.4 Cohort Growth

At each time step, cohort growth is determined by estimated LAI, water availability, temperature, capacity and uptake of nitrogen. Cohort growth generally follows the algorithms found in Century, except for N uptake. In the spring, the amount of resorbed N is calculated (leaf N- litter N), which can be “used” by the cohort the following spring. After the pool of resorbed N is depleted, the cohort takes up N from the mineral N pool. Uptake of N is proportional to ANPP, with greater N uptake by faster growing cohorts. When mineral N is limiting, competition for N between cohorts is determined by the relative amount of their coarse root biomass.

1.5 Soil and Dead Biomass Decay

All soil processes now follow the algorithm and science from Century v4.5 whereby there are four litter pools (structural and metabolic material either on the surface or within the soil) and three soil organic matter (SOM) pools.

Decay rates of SOMsurf, SOM1soil, SOM 2 and SOM 3 are now included as user inputs at the **ecoregion** scale.

1.6 Initializing Biomass and Soil Properties

The initial biomass is estimated as in the Biomass Succession extensions. **The user does not supply the initial biomass estimates.** The Century 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. Next, each cohort undergoes growth and mortality for the number of years equal to its current age. Initial cohorts therefore reflect competition among cohorts. Likewise, beginning with initial soil values, the dead and SOM pools change during the spin-up phase.

Note: *An initial (time zero) climate stream is required for initialization (see below).*

This initialization does not account for disturbances and therefore typically overestimates initial live biomass and underestimates initial dead biomass quantities.

Note: *Required computation time reflects the number of initial communities listed in the initial community file.*

1.7 Interactions with Age-Only Disturbances

Century 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 a fire or wind extensions with Century 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 the proper dead biomass pools. The interface allows a User to indicate a) whether and how much leaf or woody **live biomass** is transferred to their respective dead pools by a disturbance type and b) whether and how much of the leaf or woody **dead biomass *aboveground* pools** are removed by a disturbance type.

Note: *Do not list fire in the age-only disturbance table*. Fire effects vary by severity and are indicated in the separate **FireReductionParameters** table (below).

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 Century Succession.

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

1.8 Available Light

Available light (the conceptual inverse of shade) calculations follow the shade algorithms in Biomass Succession (v2).

1.9 Cohort Reproduction – Disturbance Interactions

See the rules and algorithm outlined for Biomass Succession (v2).

1.10 Cohort Reproduction – Initial Biomass

See the rules and algorithm outlined for Biomass Succession (v2).

1.11 Cohort Senescence and Mortality

See the rules and algorithm outlined for Biomass Succession (v2).

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1.13 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 `"Century Succession"`.

2.2 Timestep

This parameter is the time step 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 ClimateFile

The Climate File indicates a file containing required climatic inputs. **The inputs must include data for every ecoregion at time zero.** Subsequent to time zero, one or many ecoregions can have their climate data updated at any chosen time step. The format of that file is described in chapter 3.

2.7 CalibrateMode

Determines whether the model is run in calibrate mode whereby months are simulated January – December with additional output to a log file ("Century-calibrate-log.csv"). **The calibrate mode should only be used when simulating a single site due to the volume of screen output.** The intention is to allow comparison to empirical data (e.g., NEE data from flux towers) where available.

Note: *In normal mode, months are simulated July – June and all disturbances occur between June and July. Because disturbances operate at an annual time step and Century at a monthly time step, I had to choose when disturbances should occur in the Century growth cycle. Calibrate mode was set to January-December because a) that is the same as Century 4.5, and b) this cycle also matches the climate data from the various flux towers.*

Note: *The calibrate mode should only be used when simulating a single site due to the volume of screen output.*

2.8 Water Decay Function

The WaterDecayFunction parameter determines the effect of moisture on decay rate can be either linear or based on a ratio. The Century 4.0 Help file states that linear option is to be when only the relative water content in the top 15 cm affects decay rates. If ratio, the ratio of rainfall to potential evaporation rate determines the effect of moisture on decay rates.

Options: "Linear" or "Ratio"

User Tip: Linear is generally appropriate for sandy soils; ratio for more mesic soils.

2.9 ANPPMapNames

This **optional** file parameter is the template for the names of the ANPP output maps. The parameter value must include the variable "timestep" to ensure that the maps have unique names (see Section 3.1.8.1 *Variables* in the *LANDIS-II Model User Guide*). **The user must indicate if the output should be placed in a sub-directory and must indicate the file extension.** The output map units are g C m^{-2}.

In addition, an ANPPMapFrequency parameter must follow the ANPPMapNames parameter on the next line. This parameter value must be a valid time step (see Section 2.2). This parameter defines the frequency in which the maps are output, e.g., if your model Timestep is 5, then the ANPPMapFrequency value could be 5, 10, 15, etc.

2.10 ANEEMapNames

This **optional** file parameter is the template for the names of the ANEE output maps. The parameter value and map frequency is created identically to ANPPMapNames and ANPPMapFrequency (see Section 2.9).

2.11 SoilCarbonMapNames

This **optional** file parameter is the template for the names of the soil carbon output maps. The parameter value and map frequency is created identically to ANPPMapNames and ANPPMapFrequency (see Section 2.9).

2.12 SoilNitrogenMapNames

This **optional** file parameter is the template for the names of the soil nitrogen output maps. The parameter value and map frequency is created identically to ANPPMapNames and ANPPMapFrequency (see Section 2.9). The output map units are g N m^{-2}.

2.13 Probability of Establishment Adjustment

This optional parameter adjusts the probability of establishment based on the successional time step.

User Tip: If you want 1-year time step values to be equivalent to 5-year time step values, a value of 0.2 would be appropriate. If not adjustment is necessary, leave out this parameter.

2.14 AvailableLightBiomass Table

The `AvailableLightBiomass` table defines how much biomass must be at a site to achieve the five available light classes (in previous extensions, 'shade classes'). Biomass is not absolute but relative to the maximum biomass possible at a site. The table contains the relative biomass required for each available light class, 1 - 5.

2.14.1 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.

2.14.2 Available Light Class

This column contains available light class values: $1 \leq$ integer ≤ 5. The classes must be in increasing order: class 1 first and ending with class 5. Available light class 5 represents the least light (most shade). A site will be class 0 (complete light) if relative biomass ranges from 0% of maximum up to the relative biomass (%) for class 1. Likewise, if relative biomass is between the amount defined for classes 1 and 2, the site is given an available light class of 1. And so on up to class 5.

2.14.3 Relative Biomass per Ecoregion

Each ecoregion listed in the table's first row (see section 2.10.1) must have a separate column of minimum relative biomass by available light 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. Value: $0.0 \leq$ decimal number ≤ 100.0. Units: percent.

2.15 LightEstablishmentTable

Beginning with Biomass Succession (v2), the optional table `SufficientLight` was added, now named `LightEstablishmentTable`. The table allows a more nuanced site-scale P_{EST} dependent upon species light requirements (i.e., shade class) and available light. For example, if a species is mid-tolerant of low light (light requirement = 3) and the available light class is 5 (very low light), the probability may be low but not zero. If the user indicates a low probability, then there would still some small chance that a mid-tolerant can become established as may be the case in small gaps.

2.15.1 Species Shade Tolerance Class

This column contains light requirement (shade) class values: $1 \leq$ integer ≤ 5. The classes must be in increasing order: class 1 first and ending with class 5. Class 5 represents species with the lowest light requirements, i.e., the most shade tolerant.

2.15.2 Probability of Establishment, given light conditions

Each possible site-level light condition (0 – 6) has an associated probability for each species light requirement class (1 – 5). Value: 0.0 ≤ decimal number ≤ 1.0.

2.16 SpeciesParameters Table

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

2.16.1 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.

2.16.2 Functional Type

This is an index into the `FunctionalTypeParameters` table, below.

2.16.3 Nitrogen Fixers

This should be either Y or N, depending on whether the species can fix N.

2.16.4 GDD minimum/maximum

Currently, a Growing Degree Day (GDD) maximum and minimum are used to define a species climatic envelope following the algorithm by Botkin (1973). GDD is calculated on a 5°C base.

2.16.5 Minimum January Temperature

A species has a minimum tolerable January temperature (the mean of January nights). If the stochastically generated January minimum temperature is below the minimum, a species cannot establish. Units: degrees Celsius.

2.16.6 Maximum Allowable Drought

If available water follows below zero for a percent of the growing season greater than this value, a species cannot establish. Units: fraction of the growing season (0.0 – 1.0).

2.16.7 Leaf Longevity

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

2.16.8 Epicormic resprouting

Does the species resprout via epicormic branching following a fire? Value: Y/N; yes, no.

2.16.9 Lignin: Leaf, Fine Root, Wood, Coarse Root

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

2.16.10 CN Ratios: Leaf, Fine Root, Wood, Coarse Root, Litter

The carbon to nitrogen ratios for leaf, fine root, wood, coarse root, and litter components. The difference between leaf and litter CN ratios represents the amount of N that is resorbed (i.e. retranslocated) prior to leaf mortality.

Note: *For retranslocation to work properly, litter CN* ***must be*** *higher than leaf CN for each species.*

2.17 Functional Group Parameters

These parameters are either not generally resolved to the specific level or are similar across genera or species groups. **The number of functional groups cannot exceed 25.**

2.17.1 Name

The name is for display purposes only to help users organize the inputs.

2.17.2 Functional Type

An index to the species table.

2.17.3 PPDF: 1, 2, 3, 4

These four parameters define a temperature growth curve. For definitions, see the Century 4.5 help files (http://www.nrel.colostate.edu/projects/century/manual4/man96.html).

2.17.4 FRACleaf

The fraction of aboveground net primary productivity that is allocated to leaves. Units: fraction of ANPP (0.0 – 1.0).

2.17.5 BTOLAI, KLAI, MAXLAI

These three parameters determine how LAI is calculated which subsequently limits growth. Therefore these parameters help determine the initial rate of growth in the landscape. For definitions, see the Century 4.5 on-line manual (http://www.nrel.colostate.edu/projects/century/manual4/man96.html). BTOLAI determines LAI as a function of leaf biomass. KLAI and MAXLAI determine LAI as a function of wood biomass. If MAXLAI = 0.0, then only leaf biomass determines LAI and the growth limits.

2.17.6 PPRPTS2, PPRPTS3

These two parameters determine growth sensitivity to low available water, e.g., drought conditions. For definitions, see the Century 4.5 on-line manual (http://www.nrel.colostate.edu/projects/century/manual4/man96.html).

2.17.7 Woody Decay Rate

This parameter defines the maximum rate at which the species' dead wood decomposes in the ecoregion. Value: $0.0 \leq$ number ≤ 1.0. Unitless.

2.17.8 Monthly Wood Mortality

A monthly fraction of wood mortality. This replaces the algorithm in Biomass Succession v2 where growth-related mortality was a function of ANPP. Units: fraction of wood biomass (0.0 – 1.0).

User Tip: *This parameter can have large effects. If set too high, a site can remain in a permanent 'juvenile' state and woody biomass and SOM will increase very quickly and reach overly high levels. If too low, the site will reach maximum biomass too quickly and SOM may actually decline.*

2.17.9 Mortality Curve – Shape Parameter

This parameter determines how quickly age-related mortality begins and operates as in Biomass Succession v1 and v2. Value: $5.0 \leq$ decimal number ≤ 25.0. If the parameter = 5, then age-related mortality will begin at 10% of life span. If the parameter = 25, then age-related mortality will begin at 85% of life span.

2.18 Initial Ecoregion Parameters

The initial ecoregion parameters allow soils to begin with some carbon and nitrogen. However, SOM C and N at time zero will reflect the initial communities and ecoregion parameters (e.g., soil depth, field capacity, wilting point).

Note: *Dead biomass (wood, structural, and metabolic) is estimated from the growth and mortality of cohorts during initialization.*

2.18.1 Ecoregion Names

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.

2.18.2 SOM1 – 3 Carbon and Nitrogen

The initial amount of C and N in the four principle soil pools: SOM1-surface, SOM1-soil, SOM2 and SOM3. Units: g m^{-2}.

2.18.3 Mineral Nitrogen

The initial amount of mineral N. This N is available to plants for growth. Units: g m^{-2}.

2.19 Ecoregion Parameters

2.19.1 Ecoregion Names

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.

2.19.2 Soil Depth

The depth of the soil simulated, cm.

2.19.3 Percent Clay, Percent Sand

Units: fraction of soil (0.0 – 1.0).

2.19.4 Field Capacity, Wilting Point

Fraction of the soil depth. Field capacity and wilting point are calculated as this fraction multiplied by soil depth.

2.19.5 Storm Flow Fraction, Base Flow Fraction, Drain

Determines the amount of water runoff and leaching. This affects the amount of N leaching (Nloss) which, in turn, affects the amount of mineral N. For definitions, see the Century 4.5 on-line manual (http://www.nrel.colostate.edu/projects/century/manual4/man96.html).

2.19.6 Nitrogen Inputs- Slope, Intercept

Determines monthly N inputs (both deposition and biological fixation) rates as a function of precipitation.

2.19.7 Latitude

2.19.8 Decay Rates of SOM1 surface, SOM1 soil, SOM2 and SOM3

Characterizes the decomposition rate (k) of the four soil organic matter pools. For definitions, see the Century 4.5 on-line manual (http://www.nrel.colostate.edu/projects/century/manual4/man96.html) but refer to the example input file below (section 7.1) for suggested values for these parameters.

User Tip: *The decay rates should be adjusted to so that the changes in each of the soil pools between year 0 (input file) and year 1 are realistic. In most landscapes, the relative changes in the soil pools are higher in the upper than the lower horizons and the soil pools should slowly increase in soil carbon over time in the absence of disturbance.*

2.19.9 Denitrification and N volatilization

The fraction of mineral N lost through ammonia volatilization and denitrification **per month**. This fraction is not fire related; fire related volatilization is modeled separately). Units: dimensionless.

User Tip: *This parameter should be adjusted so that Nvol (output parameter of N volatilization) ranges from 0 to ~0.3 for uplands and 0.3 to 1 g m^{-2} year^{-1} for wetlands (Seitzinger et al. 2006).*

2.20 Fire Reduction Parameters

The `FireReductionParameters` table allows users to specify how much dead wood and litter will be removed as a function of fire severity. The reduction of wood and litter will occur **after** fire induced mortality of cohorts. After a fire kills a cohort, the dead biomass is deposited on the forest floor and is then subsequently volatilized in the same time step.

2.20.1 Fire Severity

The first column is fire severity, classes 1 – 5. Severity should be listed in ascending order.

2.20.2 Wood Reduction

The second column is the proportion (0.0 – 1.0) of dead wood biomass that is volatilized. The proportion will be applied to both C and N components.

2.20.3 Litter Reduction

The third column is the proportion (0.0 – 1.0) of dead litter biomass that is volatilized. The proportion will be applied to both C and N components.

2.21 Harvest Reduction Parameters

The **optional** `HarvestReductionParameters` table allows users to specify how much dead wood and litter will be removed as a function of harvest activity. The reduction of wood and litter will occur **after** harvest induced mortality of cohorts. After a harvest event kills a cohort, the dead biomass is removed from the forest. **If this table is not used, the harvested cohorts will follow the parameters in the age-only-disturbance file (see below).** *If the table is used be sure to remove harvesting from the age-only-disturbance file.*

2.21.1 Prescription Name

The first column is prescription name. Each prescription name must be identical to the prescription names in the Leaf Biomass Harvest file (see “LANDIS-II Base Harvest v2.0 User Guide”). Prescriptions can be in any order; they do *not* need to appear in the same order as in the Leaf Biomass Harvest input file.

2.21.2 Wood Reduction

The second column is the proportion (0.0 – 1.0) of dead wood biomass that is removed. The proportion will be applied to both C and N components.

2.21.3 Litter Reduction

The third column is the proportion (0.0 – 1.0) of dead litter biomass that is removed. The proportion will be applied to both C and N components.

2.22 Ecoregion-dependent Species Parameters

The Century Succession extension uses some species parameters that vary by ecoregion:

- Maximum monthly aboveground net primary production (ANPP),
- Maximum above ground biomass (AGB).

Each parameter has its own table.

2.22.1 First Row – Ecoregions

The first row in a 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 in a table's first row will have default parameter values assigned to all the species (given below). The sections below which describe the individual parameter tables also specify the default value for each table.

2.22.2 Other Rows – Species Parameters

All other rows in a table after the initial row contain species parameter values. Each row contains the parameter values for one species. The species name comes first, followed by one or more parameter values. The name and values are separated by whitespace. There must be one parameter value for each of the ecoregions listed in the table's first row.

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.

2.22.3 MaximumMonthlyANPP Table

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: g m^{-2} $month^{-1}$. Default value: 0

2.22.4 MaximumBiomass Table

This parameter defines the maximum allowable aboveground biomass (AGB) for the species in the ecoregion. Value: $0 \leq$ integer. Units: g m^{-2}. Default value: 0

2.23 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 4.

2.24 Climate Change Table

This optional table specifies changes to certain parameters that should occur during the scenario due to changes in climate. Each row in the table represents a change in the parameters at a particular year.

Note: *Because climate is dynamic via the climate input file, this feature should only be used if you have strong reason to expect either maximum ANPP or biomass to change. Typically, such data do not exist and these data are excluded.*

2.24.1 Year

This column is the year that the parameters change. Value: integer or year expression between the scenario's start and end years. Units: year.

A year expression represents a year relative to the scenario's start year or end year. The valid forms for a year expression are:

```
start          (e.g., 1990)
start+integer  (e.g., 1990+35)
end            (e.g., 2100)
end-integer    (e.g., 2100-25)
```

The names `"start"` and `"end"` refer to the scenario's start year and end year, respectively. The integer is an offset either added to the start year or subtracted from the end year.

The rows in the table must be increasing order by year; therefore, the year in a row must be greater than the year in the previous row.

2.24.2 Parameter File

This column is the path to a text file that contains the new parameter values to use. The format of the file is described in chapter 6.

3 Input File – Climate Data

This required auxiliary data file contains the weather data necessary for calculating cohort growth and soil decomposition.

3.1 LandisData

This parameter's value must be `"Climate Data"`.

3.2 ClimateTable

The climate table must include data for every ecoregion for time zero. Time zero is used during the initialization ('spin-up') phase and is the default climate if no other data are provided.

3.2.1 Ecoregion Index

The first column corresponds to an active ecoregion as 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. **Ecoregion index corresponds to the ecoregions input file where index=0 is the first ecoregion in the list; index=(N-1) is the last ecoregion in the list.**

3.2.2 Time step

Integer: 0 – number of simulation years. The weather data will be updated even if the climate time step does not match the succession time step. Weather will be stochastically generated based on the averages and standard deviations provided ***every year***. If a year is not provided, weather will be generated based on the last update year or year zero, whichever is largest.

3.2.3 Month

1 – 12. All 12 months must be provided.

3.2.4 Average Minimum Temperature

Average night-time temperatures for the entire month. May be further averaged across years. Units: degrees Celsius.

3.2.5 Average Maximum Temperature

Average day-time temperatures for the entire month. May be further averaged across years. Units: degrees Celsius.

3.2.6 Standard Deviation Temperature

Standard deviation of mean temperatures for the entire month. May be averaged across years. Units: degrees Celsius.

3.2.7 Average Precipitation

Average precipitation across years. Units: cm.

3.2.8 Standard Deviation Precipitation

Standard deviation of precipitation across years. Units: cm.

3.2.9 Photosynthetically Active Radiation (PAR)

These values are not used in the Century Succession and will be ignored. However, a value (e.g., 0.0) must be provided.

4 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.

4.1 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
```

4.2 LandisData

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

4.3 Initial Community Class Definitions

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

4.3.1 MapCode

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

4.3.2 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.

4.3.3 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
```

5 Input File – Age-only Disturbances

This optional auxiliary input file contains the biomass parameters used when age-only disturbances kill biomass cohorts (see section 2.18 *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*.

Note: *Fire is not allowed as a disturbance type*. Fire effects vary by severity and are indicated in the FireReductionParameters table.

5.1 LandisData

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

5.2 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.

5.2.1 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.

5.2.2 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.

5.2.3 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.

5.3 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.

5.3.1 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.

5.3.2 Woody

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

5.3.3 Non-Woody

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

6 Input File – Climate Change

This optional auxiliary input file contains an updated set of biomass parameters that represent the effects of climate change (see section 2.19 *Climate Change Table*). 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*.

6.1 LandisData

This parameter's value must be `"Century Succession – Climate Change"`.

6.2 MaximumMonthlyANPP Table

This table contains the maximum ANPP (aboveground net primary production) for species in various ecoregions. The table has the same format as its counterpart in the main input file (see above).

6.3 MaximumBiomass Table

This table contains the maximum biomass for species per ecoregion. The table has the same format as its counterpart in the main input file (see above).

7 Example Inputs

7.1 Main Parameter File

```
LandisData  "Century Succession"

Timestep  1

SeedingAlgorithm  WardSeedDispersal

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

ClimateFile ClimateInputsMultipleYear.txt

CalibrateMode   yes  << Calibrate mode assumes no disturbances and runs the months 1 - 12.

SpinupMortalityFraction 0.002

WaterDecayFunction Ratio <<Linear or Ratio

ProbEstablishAdjust 1

ANPPMapNames    century/ag_npp-{timestep}.gis
ANPPMapFrequency    5
ANEEMapNames    century/nee-{timestep}.gis
ANEEMapFrequency    5

AvailableLightBiomass
>> Available Relative Biomass
>> Light by Ecoregions
>> Class
>> ----------   --------------------
           eco1

   1 15%
   2 25%
   3 50%
   4 80%
```

```
   5 95%

SufficientLightTable
>> Spp Shade Probability
>> Class by Actual Shade
>> ----------   --------------------
>>    0   1   2   3   4   5
   1 1.0 0.1 0.0 0.0 0.0 0.0
   2 1.0 1.0 0.1 0.05    0.0 0.0
   3 1.0 1.0 1.0 0.1 0.05    0.0
   4 1.0 1.0 1.0 1.0 0.1 0.05
   5 0.1 0.5 1.0 1.0 1.0 1.0

SpeciesParameters

>>Species  Funct   N   GDD  GDD  Min  Max     Leaf  Epi-     Leaf    FRoot   Wood    CRoot   Leaf  FRoot Wood  CRoot Littr
>>ional    Toler       Min  Max  Jan  Drought Long  cormic   Lign%   Lign%   Lign%   Lign%   CN    CN    CN    CN    CN
>>Type ance            Temp                          re-
>>                                              sprout
>>
   abiebals   2    N   560  2386 -25  0.165   3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   acerrubr   1    N   1260 6600 -18  0.23    1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   acersacc   1    N   1222 3100 -18  0.268   1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   betualle   1    N   1100 2500 -18  0.200   1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   betupapy   4    N   484  2036 -28  0.280   1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   fraxamer   1    N   1398 5993 -12  0.280   1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   piceglau   2    N   280  1911 -30  0.309   3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   pinubank   2    N   830  2216 -30  0.411   3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   pinuresi   2    N   1100 2035 -20  0.385   3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   pinustro   2    N   1100 3165 -20  0.310   3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   poputrem   4    N   743  2461 -30  0.267   1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   querelli   3    N   2000 2234 -15  0.28    1.0    N      0.175   0.23    0.23    0.23    30    48    500   333   50
   querrubr   1    N   1100 4571 -17  0.225   1.0    N      0.175   0.23    0.23    0.23    30    48    500   333   50
   thujocci   2    N   1000 2138 -20  0.35    4.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100
   tiliamer   1    N   1400 3137 -17  0.2     1.0    N      0.223   0.255   0.255   0.255   20    45    90    90    45
   tsugcana   2    N   1324 3800 -18  0.18    3.0    N      0.2     0.2     0.35    0.35    50    50    380   170   100


FunctionalGroupParameters  <<from tree.100                                                        Age     Leaf
>> Name    Index   PPDF1   PPDF2   PPDF3   PPDF4   FCFRAC BTOLAI  KLAI  MAXLAI PPRPTS2 PPRPTS3 Wood    Monthly Mort    Drop
>>                 T-Mean  T-Max   T-shape T-shape  leaf                                        DecayR  WoodMo  Shape   Month
SMAPLE     1       20.0    32.0    0.2     8.0      0.5  0.00823 1000   20.0     1.0     0.8  0.4     0.003   10      9
WPINE      2       15.0    32.0    1.0     3.5      0.37 0.00823 1000   10.0     1.0     0.8  0.4     0.003   10      10
HVFST      3       25.0    45.0    1.0     3.0      0.5  0.00823 1000   20.0     1.0     0.8  0.4     0.003   10      9
ASPEN      4       20.0    32.0    0.2     10.0     0.5  0.00823 1000   20.0     1.0     0.8  0.4     0.003   10      9
```

```
InitialEcoregionParameters
>> Name  SOM1    SOM1    SOM1    SOM1    SOM2    SOM2    SOM3    SOM3    Minrl
>>       C       N       C       N       C       N       C       N       N
>>       surf    surf    soil    soil
Eco3     110     6       150     17      4500    145     1294.0  50      20.0

EcoregionParameters
>>    Soil Percent  Percent  Field   Wilt   StormF BaseF   Drain   Atmos   Atmos   Lat-    Decay Decay   Decay   Decay Denitrif
>>    dep  Clay     Sand     Cap     Point  Fract  Fract           N       N       itude   Rate  Rate    Rate    Rate
>>    cm   frac     frac                                           slope   inter           Surf  SOM1    SOM2    SOM3

eco3  100  0.069    0.591    0.3     0.2    0.4    0.4     0.75    0.05    0.05    44.0    0.4   1.0     0.02    0.0002 0.02

FireReductionParameters
>> Severity Wood   Litter
>> Fire     Reduct Reduct
   1        0.0    0.5
   2        0.05   0.75
   3        0.2    1.0
   4        0.5    1.0
   5        0.8    1.0

MonthlyMaxNPP <<PRDX(3) from Century 4.0 (g Biomass / m2)

>> Species      Ecoregions
>> --------     ------------------
            eco3

abiebals    150
acerrubr    200
acersacc    200
betualle    200
betupapy    200
fraxamer    200
piceglau    200
pinubank    150
pinuresi    150
pinustro    150
poputrem    200
querelli    200
querrubr    200
```

```
thujocci    150
tiliamer    200
tsugcana    150


MaxBiomass

>> Species      Ecoregions
>> --------     ------------------
            eco3

abiebals    20000
acerrubr    15000
acersacc    25000
betualle    25000
betupapy    17500
fraxamer    25000
piceglau    18000
pinubank    15000
pinuresi    20000
pinustro    17500
poputrem    15000
querelli    20000
querrubr    20000
thujocci    20000
tiliamer    25000
tsugcana    25000



AgeOnlyDisturbances:BiomassParameters  bio-reductions-standard.txt

>> ********************
   ClimateChange

>> Year  Parameter File
>> ----  --------------
   1990   climate-change/input-1990.txt
   2025   climate-change/input-2025.txt
   2100   "climate-change/input-2100.txt"
```

7.2 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%
```

7.3 Climate Input

```
LandisData "Climate Data"

ClimateTable
>>Eco`   Time   Month  AvgMinT    AvgMaxT    StdDevT    AvgPpt StdDevPpt
>>Name   Step          (C)        (C)                   (cm)
eco1     0   1      -17.81 -6.14  3.17   3.1 1.76
eco1     0   2      -16.67 -3.54  2.87   2.3 1.57
eco1     0   3      -10.6  2.22   2.7 4.6 2.43
eco1     0   4      -2.11  10.75  2.05   6   2.86
eco1     0   5      4.46   18.56  2.09   8.4 4.32
eco1     0   6      10.13  23.27  1.47   9.7 5.56
eco1     0   7      12.7   25.91  1.42   10.1   4.97
eco1     0   8      11.47  24.6   1.55   11.5   5.57
eco1     0   9      6.99   19.52  1.52   9.9 5.65
eco1     0   10     1.47   13.03  2.09   6.8 3.51
eco1     0   11     -5.49  3.32   2.18   5.8 3.15
eco1     0   12     -13.3  -3.68  2.83   3.3 1.58
```

```
>>2000
eco1 1   1      -15.40 -6.44  0.00   3.06   0.00
eco1 1   2      -9.84  -0.33  0.00   4.70   0.00
eco1 1   3      -3.72  6.53   0.00   3.70   0.00
eco1 1   4      -1.88  9.46   0.00   6.12   0.00
eco1 1   5      6.37   18.10  0.00   5.11   0.00
eco1 1   6      9.26   19.03  0.00   13.17  0.00
eco1 1   7      12.38  21.29  0.00   10.90  0.00
eco1 1   8      12.47  21.52  0.00   3.88   0.00
eco1 1   9      7.00   16.59  0.00   5.68   0.00
eco1 1   10     3.68   13.87  0.00   4.01   0.00
eco1 1   11     -4.82  1.24   0.00   4.10   0.00
eco1 1   12     -18.40 -10.12 0.00   2.48   0.00
```