# LANDIS-II Age-Only Succession v2.0 Extension User Guide

Robert M. Scheller
James B. Domingo

University of Wisconsin-Madison

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# 1 Introduction

This document describes the **Age-Only Succession** extension to the LANDIS-II model. For information about the model and its core concepts, see the *LANDIS-II Conceptual Model Description.*

In general, the Age-Only Succession extension follows the assumptions about succession of previous LANDIS versions, 3.x and earlier (Mladenoff et al. 1996). The largest change is to the seed dispersal algorithm which now follows the algorithm described in Ward et al. (2005) and the white paper provided on the LANDIS-II web site (www.landis-ii.org/documentation).

## 1.1 What's new in version 2.0

This document describes the current version (2.00) of the extension.

- Previous versions of LANDIS applied an assumption that species cohorts younger than their age of sexual maturity did not cast shade. This assumption was implemented as a proxy for crown closure, assuming that opportunities for species establishment existed prior to the onset of direct competition for light. Version 2.0 now includes this assumption to be most compatible with earlier versions of LANDIS.

## 1.2 Shade Calculation

Shade is calculated using the cohorts present on a site. Shade at a site is the maximum shade tolerance of all species present.

$$\text{Site shade} = \text{maximum (cohort shade tolerance} \in \text{[all cohorts with ages} > \text{maturity age])}$$

## 1.3 Cohort Reproduction

Cohort reproduction requires three prior events to occur: 1) A propagule must exist, either through seeding, resprouting, or planting. 2) There must be adequate light. 3) The probability of species establishment must exceed a random number. A complete explanation of these functions can be found in the *LANDIS-II Conceptual Model Description*.

Cohort reproduction is simply the addition of a cohort, aged 1 year. No further information is computed or required. **Note: this initial**

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

## 1.1 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.

## 1.2 Cohort Ageing

Cohort ageing is simply the addition of the time step to each existing cohort. No further information is computed or required. A complete explanation of these functions can be found in the *LANDIS-II Conceptual Model Description*.

## 1.3 Cohort Mortality

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

In this extension, there is also an increasing probability of random mortality for each cohort after the cohort has passed 80% of its maximum lifespan (the longevity). This age-related mortality begins at 0.2 if the cohort has reached 80% of its maximum lifespan. At the end of its lifespan, the probability will be near 1.0.

In previous versions of the LANDIS model with decadal time steps, the probability of random age-related mortality ($P_{arm}$) is:

$$P_{arm,\ decadal} = 0.2 + \left[ \frac{longevity}{5} + \left( age - longevity \right) \right] \left( \frac{0.8}{0.2\ longevity} \right)$$

Because the LANDIS-II model has a variable time step, an annual probability is computed:

$$P_{arm,\ annual} = \frac{P_{arm,\ decadal}}{10}$$

This annual probability is used when cohort ages are updated (see section 4.4.1 *Ageing* in the *LANDIS-II Conceptual Model Description*). If a cohort's age is at least 80% of its longevity, then a random number is generated for each year that its age has been advanced. Each random number is compared to the age-related probability; if it is less than or equal to the probability, then the cohort dies.

## 1.4 Version History

### 1.4.1 Version 1.3 (July 2008)

The differences between this version and the previous version (1.2) include:

- A structural change to the succession library interface required an update of version number.

### 1.4.2 Version 1.2

The differences between version 1.2 and the previous version (1.1) include:

- The patch to repair a bug with post-fire regeneration. Because of the bug, cohorts killed by fire disturbances were not triggering post-fire reproduction.
- Corrected the description of the shade calculation in section 1.2 of this document so it matches the actual calculation in the code.

### 1.4.3 Version 1.1

The differences between version 1.1 and the previous version (1.0) include:

- Modifications so that the extension is compatible with version 5.1 of the LANDIS-II model.
- The fix that was distributed in the LANDIS-II 5.0 Service Pack 1 to correct the “donut” bug in the Ward seed dispersal algorithm.
- The implementation of the random age-related mortality for cohorts described in section 1.3 *Cohort Mortality*. It was missing from the previous version.
- Significant enhancements to the component that represents age cohorts. These changes came about from the work on the Biomass Succession extension. They ensure that disturbance extensions for age cohorts (e.g., Base Fire and Base Wind) will work with biomass cohorts as well.

## 1.5 References

Mladenoff, D. J.; Host, G. E.; Boeder, J., and Crow, T. R. LANDIS: A spatial model of forest landscape disturbance, succession, and management. Goodchild, M. F.; Steyaert, L. T.; Parks, B. O.; Johnston, C. A.; Maidment, D.; Crane, M., and Glendinning, S., editors. GIS and environmental modeling: progress and research issues. Fort Collins, Colorado, USA: GIS World Books; 1996; pp. 175-179.

Scheller, R.M., J.B. Domingo, D.J. Mladenoff, E.J. Gustafson, B.R. Sturtevant. Introducing LANDIS-II: design and development of a collaborative landscape simulation model with flexible spatial and temporal scales. Ecological Modelling. *In review.*

Ward, B. C.; Mladenoff, D. J., and Scheller, R. M. Landscape-level effects of the interaction between residential development and public forest management in northern Wisconsin, USA. Forest Science. *In Press*.

Ward, B. C. and Scheller, R. M. Technical Document: Double Exponential Seed Dispersal. Online: http://landis.forest.wisc.edu/documentation.

## 1.6 Acknowledgments

Funding for the development of LANDIS-II has been provided by the North Central Research Station (Rhinelander, Wisconsin) of the U.S. Forest Service. Valuable contributions to the development of the model and extensions were made by Brian R. Sturtevant, Eric J. Gustafson, and David J. Mladenoff.

# 2 Parameter Input File

The input parameters for this extension are specified in one 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 `"Age-only Succession"`.

## 2.2 Timestep

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

## 2.3 SeedingAlgorithm

This parameter is the seeding algorithm that the extension uses. 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 Establishment Probabilities Table

Recall that sites with similar abiotic conditions are grouped into a single land type or **ecoregion**. Each ecoregion requires a **probability of species establishment** (**$P_{EST}$**) for each species. **NOTE:** PEst is not automatically adjusted for succession time step in this extension. **The user is responsible for supplying $P_{EST}$ values that correspond to the chosen successional time step.**

$P_{EST}$ data are contained within a table.

### 2.4.1 Table Name

The table's name is `"EstablishProbabilities"`.

### 2.4.2 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 values assigned to all the species. This default value is 0.

### 2.4.3 Other Rows – Establishment Probabilities per Species

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

The species can be listed in any order in a table. And a species can be omitted; in which case, it will be assigned the default value of 0 for all active ecoregions.

# 3 Example File

```
LandisData  "Age-only Succession"

Timestep  10

SeedingAlgorithm  WardSeedDispersal
>> Also NoDispersal or UniversalDispersal

EstablishProbabilities

>> Species        Ecoregions
>> --------       -------------
                  eco1    eco2

   abiebals       0.9     0.05
   acerrubr       1.0     0.6
   acersacc       0.82    0.3
   betualle       0.64    0.24
   betupapy       1.0     0.75
   fraxamer       0.18    0.1
   piceglau       0.58    0.5
   pinubank       1.0     0.8
   pinuresi       0.56    0.78
   pinustro       0.72    0.70
   poputrem       1.0     0.8
   querelli       0.96    0.71
   querrubr       0.66    0.43
   thujocci       0.76    0.002
   tiliamer       0.54    0.06
   tsugcana       0.22    0.01
```