

# LANDIS-II Age-Only Succession v4.0 Extension User Guide

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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](http://www.landis-ii.org/documentation)).

## 1.1 What's new in version 4.0 (July 2014)

This document describes the current version (4.0) of the extension.

This version adds the capability for species establishment coefficients to vary through time.

## 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.

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

## 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:

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

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 3.0

This document describes the current version (3.0) of the extension.

This version applies the restriction that a species must have an establishment probability  $> 0$  for planting (within a Harvest prescription) to be successful. This behavior is now consistent with the general Model Description.

#### 1.4.2 Version 2.0

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.

#### 1.4.3 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.

#### 1.4.4 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.

#### 1.4.5 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

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## 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 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 Establishment Probabilities File

Recall that sites with similar abiotic conditions are grouped into a single land type or **ecoregion**. Each YEAR and ECOREGION combination 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 separate file.

#### 2.6.1 LandisData Name

The file's name is "Dynamic Input Data".

#### 2.6.2 First Row – Year

The first row is the simulation year. YEAR ZERO MUST BE INCLUDED. The  $P_{EST}$  data are updated whenever the simulation year matches the integer found in the row. If you only include year zero, then  $P_{EST}$  will remain constant through the entirety of the simulation.

### 2.6.3 Second Row – Ecoregions

The second row 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 in a table's first row will have default values assigned to all the species. This default value is 0.

### 2.6.4 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 Primary Input File

```
LandisData  "Age-only Succession"

Timestep  10

SeedingAlgorithm  WardSeedDispersal
>> Also NoDispersal or UniversalDispersal

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

DynamicInputFile       age-only-succession-dynamic-inputs.txt
```

## 4 Example Dynamic Inputs File

```
LandisData "Dynamic Input Data"

>> Year Ecoregion Species ProbEst
>> -----
0 eco1 abie bals 0.9
0 eco1 acerrubr 1.0
0 eco1 acersacc 0.82
0 eco1 betualle 0.64
0 eco1 betupapy 1.0
0 eco1 fraxamer 0.18
0 eco1 piceglau 0.58
0 eco1 pinubank 1.0
0 eco1 pinuresi 0.56
0 eco1 pinustro 0.72
0 eco1 poputrem 1.0
0 eco2 pinuresi 0.78
0 eco2 pinustro 0.70
0 eco2 poputrem 0.8
0 eco2 querelli 0.71
0 eco2 querrubr 0.43
0 eco2 thujocci 0.002
0 eco2 tiliamer 0.06
0 eco2 tsugcana 0.01
```

## 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:  $0 \leq \text{integer} \leq 65,535$ . Each class' map code must be unique. Map codes do not have to appear in any order, and do not need to be consecutive.

### 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 (see section **Error! Reference source not found.**). 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
```