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# Land Use v2.0 LANDIS-II Extension User Guide

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## 1 Introduction

This document describes the Land Use extension (LU+) for the LANDIS-II model. Users should read the *LANDIS-II Conceptual Model Description* and the *LANDIS-II Model v6.0 User Guide* prior to reading this document.

This extension allows users to incorporate a sequence of maps depicting changes in land use or land cover into LANDIS-II simulations. Maps can be developed manually in a Geographic Information System, or derived from an external program (e.g., Dynamica). Map values correspond to land use or land cover classes, and a change in map value at a site from one time step to the next indicates a change in land use or land cover.

In LU+, the user can model how cohorts will be removed if a change in the land use or land cover results in forest loss or disturbance. In the input text file where map values are identified, the user specifies the species to be removed, species to be planted, or if establishment of new cohorts is prevented.

These capabilities can be used to simulate, for example, total removal of cohorts and prevention of establishment of new cohorts as a result of a site being converted from forest to developed land. In addition, users can also specify whether or not a change in land use or land cover removes a site from consideration for timber harvesting in subsequent time steps, as in the case of a new conservation easement or forest preserve being established.

**Important note:** Land-Use Change is designed to operate with other extensions in a modular way within the framework of LANDIS-II. However, the order in which extensions are specified in the “scenario” input file to LANDIS-II may affect the outcome of simulation experiments. For example, when implementing both the Biomass Harvest and the Land Use Change extension, both contain functionality for removing cohorts of trees from a landscape. Changing the order in which these extensions are specified in the “scenario” file changes the order that the logic is applied in the simulation, which can affect the outcome of simulations.

### 1.1 Pause Functionality

Additional routines can be executed at the end of each timestep by specifying external scripting tools for performing additional

transformations on landscape data. This can be accomplished two ways: by specifying a console command or providing PATHs to a scripting engine (.exe) and an eligible script file. These parameters are documented in section (2). Land-Use will ignore pause functionality if none of the pause parameters are specified.

## 1.2 Repeat Harvesting

(new in v2.0) - Harvest or defoliating of tree cohorts can now take place yearly, despite the time-step being used in the model (RepeatHarvest on), or only the year when the pixel switches to the given land use type (RepeatHarvest off).

## 1.3 Insect Defoliation

(new in v2.0) Land use categories can now include a percent defoliation to be applied to cohorts of trees for simulating insect outbreaks or other causes of defoliation. Different age cohorts of the same species can be defoliated in different proportions. **InsectDefoliation requires a specific version of the PnET Succession extension (see below)**

## 1.4 Requirements

This extension is compatible with LANDIS-II version 6 series. The libraries required for proper functioning of our extension are included on the deployment page of our GitHub:

<https://github.com/LANDIS-II-Foundation/Extension-Land-Use-Change/tree/master/deploy/libraries>

Use of these libraries requires installation of the proper version, listed below (LANDIS-II core libraries not included, should be standard):

Extension BiomassHarvest: v3.2+

Extension PnET-Succession: v2.1+

(Insect Defoliation) Extension PnET-Succession: v2.2 (exact)

<https://github.com/LANDIS-II-Foundation/Extension-PnET-Succession/tree/LUv2.0>

(InsectDefoliation) Extension Output-PnET: v2.2 (exact)

[https://github.com/LANDIS-II-Foundation/Extension-Output-Biomass-PnET/tree/LANDIS\\_6.2\\_LU\\_2.0](https://github.com/LANDIS-II-Foundation/Extension-Output-Biomass-PnET/tree/LANDIS_6.2_LU_2.0)

Extension Biomass Succession version 3.2+

Extension Output Biomass v2.1+ is required to output biomass maps.

Library AgeOnlyCohorts	Assembly Version: v2.1.5520.27591
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Library Biomass-v1.0.1	Assembly Version: 1.0.1.0
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Library SiteHarvest-v1	Assembly Version: 1.0.6492.27595
------------------------	----------------------------------

Library Succesion-v5	Assembly Version: 5.0.6491.14006
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## 1.5 Revision History

### 1.5.1 Version 2.0

#### v2.0 - official release (May 2018)

Support for repeat harvesting in LandCoverChanges on LandUses  
Multiple LandCoverChange types on LandUses  
Added InsectDefoliation as a new type of LandCoverChange type.

### 1.5.2 Version 1.2

#### v1.2 – official release (May 2017)

- Pause functionality for transforming data between model run timesteps was added.

### 1.5.3 Version 1.1

#### v1.1 - - official release (March 2016)

- The project was updated to work with the latest Biomass Harvest Library version (1.1).

### 1.5.4 Version 1

#### v1.0 – official release (November 8, 2015)

- The project was upgraded for the latest LANDIS-II version (6.1).
- The source code for the project was relocated to GitHub.

#### v1.0 – release candidate 1 (June 28, 2015)

The initial public release.

## 1.6 Acknowledgements

Funding for the development of this extension was provided by Harvard Forest, the Dynamics of Coupled Natural and Human Systems (CNH) Program of the National Science Foundation (USA), and the University of Notre Dame.

## 2 Input Files

This extension has two types of input files: a text file with input parameters (section Error: Reference source not found) and a set of land use maps (section ). When using pause functionality, external scripts for a given programming language must be specified (see example R script at end of the documentation)

### 2.1 Land Use Maps

This extension requires a time-series of thematic raster maps. The maps represent the land uses for active sites throughout the simulation. One land-use map must be provided for the first time step (0). Users can optionally supply maps for each extension time step, as well as using our Pause functionality to generate maps on-the-fly from model output at each timestep. In the map for time step  $t$ , the value at cell  $(row, column)$  is the map code (section 3.2) for the land use at the site  $(row, column)$  at time  $t$ . The initial land use for each active site is specified in the map for time step 0. The naming conventions for the maps are provided below in section 2.2.3.

#### 2.1.1 Land Use Change Events

When reading the land use map for time step  $t$ , the extension determines if a site's land use has changed since the previous time step:

$$LU(site, t - \Delta t_{\text{LAND USE}}) \neq LU(site, t) \Rightarrow \text{land use change event at } site$$

When a site's land use changes, the extension applies the land-cover change (section 3.5) associated with the new land use,  $LU(site, t)$ , to the site.

### 2.2 Input Parameters

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

#### 2.2.1 LandisData

This parameter's value must be "Land Use".

#### 2.2.2 Timestep

This parameter is the extension's time step,  $\Delta t_{\text{LAND USE}}$ . Value: integer > 0. Units: years.

### 2.2.3 InputMaps

This parameter identifies the time series of land-use maps. The value is a template for the file paths of the maps. The variable “{timestep}” must be included as part of the template; it is replaced with the current time step to generate the file path of the land-use map for the current time step (section 3.1.8.1 of *LANDIS-II Model v6.0 User Guide*). The image file format (e.g., .img, .tif, etc.) must also be included.

Example:

InputMaps     ./land-use-{timestep}.img

In the given example, the series of maps (format is ERDAS IMAGINE) are stored in the current working directory as (assuming a 10-year time step): land-use-10.img, land-use-20.img, etc.

### 2.2.4 SiteLog

This is an optional parameter that is the file path of the extension's event log file. If this parameter is present, a log file in CSV format will be written that identifies the 1) timestep; 2) row and column; 3) and biomass ( $\text{g/m}^2$ ) removed by species. **Warning:** This file can become extremely large.

Example:

SiteLog        ./land-use/site-log.csv

### 2.2.5 ExternalExecutable

PATH to an executable (.exe) program for processing script files executed during pause functionality. Rscript.exe for example (see example R script and scenario file at the the end of the documentation). This must be specific to the programming language for the script file.

### 2.2.6 ExternalScript

PATH to a script file on the local machine e.g. Python (.py), R (.r), Matlab (.m) to be executed each time step by the pause functionality. Errors will occur if script file does not match the programming language given by the executable (.exe).



### 2.2.7 ExternalCommand

A string console command to be executed by the Windows Command Prompt each timestep in place of an executable. Offers more flexibility with the potential for specifying inputs from the command line. Overrides ExternalExecutable and ExternalScript if specified.

### 2.2.8 Land Uses

The rest of the input file is a list of one or more land-use definitions. The format of these land-use definitions is described in the next chapter.

### 3 Land Use Definitions

Each land use is defined by a block of parameters in the input file (section Error: Reference source not found). The following sections describe the parameters that are required and optional for each land-use definition.

#### 3.1 LandUse

This parameter defines the name of a particular land use. If the name includes more than one word separated by spaces, it must be enclosed in double quotes.

Example:

LandUse        “Residential Development”

#### 3.2 MapCode

This parameter is the unique value that represents the land use in input maps (section 2.1 above). Value: integer between 0 and 65,535 (16 bits).

Example:

MapCode        1, 234, 7762 (smaller numbers simpler)

#### 3.3 PreventEstablishment

This optional keyword will prevent establishment within all sites implementing this particular LandUse, designed for use with the RemoveTrees LandCoverChange. However, any remaining cohorts on the site will continue to grow. The concept is designed to mimic the effects of housing development when sites are fully or partially harvested and do not regenerate back to forest.

**Note:** once a land use with PreventEstablishment is assigned to a site, establishment can be re-enabled using the most recent version of the LANDIS Succession (v5, see requirements section above) library, which contains a method EnableEstablishment in the Reproduction class.

#### 3.4 AllowHarvest?

This parameter indicates whether or not the land use allows timber harvesting. Valid values are *yes* or *no*, as described in section 3.1.6 of the *LANDIS-II Model v6.0 User Guide*. The default value is *yes*, so

specification is only required when preventing harvest, as in the following example:

Example:

```
AllowHarvest?    no
AllowHarvest?    No
AllowHarvest?    n
```

**Note:** If given a value of *no*, those sites with this land use will be excluded from the calculation of `StandSiteCount` by the Base or Biomass Harvest extensions in later time steps. This will have the effect of reducing the calculated size of a stand, which may impact stand ranking within a management unit or achievement of size targets for individual harvests.

### 3.5 LandCoverChange

These parameters specify the land cover changes associated with the land use. The parameters indicate changes to trees over time as a site whether trees are removed from a site when the land use is applied to the site. Current valid values are: `NoChange`, `RemoveTrees`, `InsectDefoliation`.

Example:

```
LandCoverChange  NoChange
```

If the value `NoChange` is specified, the land use definition requires no additional parameters. Note that it is possible to have multiple `LandCoverChanges` applied to a single `LandUse`

Example:

```
LandCoverChange RemoveTrees
```

...

```
LandCoverChange InsectDefoliation
```

Note: due to the way `RemoveTrees` is implemented with Harvesting modules in the background, tree removal will happen instantaneously in the first timestep of the landscape, whereas `InsectDefoliation` will be delayed until the end of the time step size until after succession occurs.

Repeat Harvests

Normally changes to a site associated with LandCoverChanges are only applied when a site transitions to a LandUse associated with a set of LandCoverChanges from a different LandUse (for example, LandCoverChanges associated with an agricultural LandUse are applied immediately following change from a forested LandUse).

LandCoverChanges can be applied each timestep to the same site repeatedly through the optional RepeatHarvest parameter. The default behavior is not to repeat harvests across timesteps. **For each LandCoverChange on a LandUse**, users can invoke repeat harvests in the following way:

LandCoverChange RemoveTrees

RepeatHarvest? Yes

Examples: if RepeatHarvest is not enabled for RemoveTrees, tree removal will only occur once. If it is not enabled for InsectDefoliation, only one round of defoliation will occur.

### 3.6 Parameters When Removing Trees

If the LandCoverChange parameter is `RemoveTrees`, then the land use definition requires additional parameters.

#### 3.6.1 Species List

A list of species to remove is required. This list must include at least one species. If there are multiple species, each is on a separate line. The species do not need to appear in any particular order.

After each species' name, the ages and age ranges that will be removed are listed. An individual age cannot be repeated in the list. Ranges cannot overlap nor include any listed individual age.

The user may specify a percent biomass to be removed after an age or age range. The percentage indicates what proportion of a cohort will be removed. The default percentage is 100%.

Example:

```
acersacc 1-40(50%) 50(65%) 65-70 71-107(15%)
```

#### 3.6.2 Plant

This optional keyword indicates that which species should be planted at a site after trees are cut. Value: A list of one or more species names separated by whitespace.

Example:

Plant pinustro

### 1.1 Parameters for InsectDefoliation

When users specify insect defoliation as a LandCoverChange a few parameters are required:

LandCoverChange InsectDefoliation

PIST 1(25%)

Specifying a list of species with an age or age-range and a percentage defoliation rate, where 100% is the default. The structure is identical to that of RemoveTrees, see above for examples and explanation. There is one caveat: while specifying an age or age-range is required, InsectDefoliation does not currently support different defoliation percentages for different cohorts within a species. The last percentage specified will be applied to all members of a species on a site.

## 2 Example Input File

```

LandisData "Land Use"

Timestep 10
InputMaps land-use-{timestep}.img
SiteLog land-use/site-log.csv << optional: default = don't generate log

ExternalScript external_module.py
ExternalExecutable C:/Python27/ArcGIS10.4/python.exe
ExternalCommand "python external_module.py"

>>-----
LandUse forest
>>-----
MapCode      1
AllowHarvest? yes
LandCoverChange NoChange

>>-----
LandUse "Urban development"
>>-----
MapCode      2
AllowHarvest? No
PreventEstablishment
LandCoverChange RemoveTrees
RepeatHarvest? Yes
    PIST 1-300(100%)
    TSCA 1-300(100%)
    FAGR 1-300(100%)
LandCoverChange InsectDefoliation
RepeatHarvest? Yes
    PIST 1-300(10%)
    TSCA 1-300(10%)
    FAGR 1-300(10%)
    Plant PIST

>>-----
LandUse "Garden"
>>-----
MapCode      3
AllowHarvest? no
LandCoverChange RemoveTrees
    PIST 1-10(100%)
    Plant PIST
    RepeatHarvest? Yes
LandCoverChange InsectDefoliation
    PIST 1 (15%)
    RepeatHarvest? No

>>-----
LandUse "no-harvest easement"
>>-----
MapCode      4
AllowHarvest? no
LandCoverChange NoChange

```