Base Wind Extension for LANDIS-II
User's Guide (v1.0)

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1 Introduction

This document describes the Wind extension (‘plug-in’) for the LANDIS-II model. Readers should read the LANDIS-II Core User’s Guide prior to reading this document.

The wind module described herein follows the behavior of the wind behavior as described in Scheller and Mladenoff (2004). There are three critical differences between this implementation and earlier implementations.

First, wind initiation and spread are not dependent upon forest condition and there is a probability of a storm initiating at each cell at each time step. This more closely resembles actual wind events. The probability of a wind event at each time step is determined by a Wind Rotation Period (input by the User).

To calculate wind probability for a site:

\[ \text{probPerSite} = \frac{\text{timeStep} \text{ (yrs)} \times \text{siteSize} \text{ (ha)} \times \text{RotationPeriod} \text{ (yrs)}}{\text{meanWindSize} \text{ (ha)}} \]

Second, each wind event is given a single intensity (drawn from a uniform random distribution) that representing mean wind speed.

Lastly, wind size and frequency parameters are unique for each ecoregion.

1.1 Landscape Data

The Base Wind extension adds one site variable to the landscape: time-since-last-wind-event (years). These data can be seen by all other extensions.

1.2 References

2 Wind Disturbances

During a wind time step, multiple wind events may happen on the landscape.

2.1 Wind Rotation Period (WRP)

The User input wind rotation period is used to derive the wind event probability (WEP) (see above). The WRP is input for each ecoregion.

A wind event can start at any active site on the landscape. To determine if an event is initiated at a site, a random number between 0.0 and 1.0 is generated (uniform distribution) and compared with the WEP. If the number is ≤ the WEP, an event starts at the site:

\[ \text{random} \sim U(0, 1) \leq \text{WEP} \text{ for site's ecoregion} \rightarrow \text{wind event starts} \]

2.2 Event Intensity

Each wind event has an intensity. The intensity is currently drawn from a uniform random distribution, scaled from 0 to 1.0: random \(U(0, 1)\). The wind intensity represents mean wind speed.

2.3 Event Size

A wind event has a size (units: hectares) that is calculated from wind-event parameters associated with the initiation site’s ecoregion:

- minimum wind size (hectares), MinWS
- maximum wind size (hectares), MaxWS
- mean wind size (hectares), MeanWS

The size is a random number generated using a negative exponential distribution whose mean is MeanWS.

\[ \text{size generated} = \text{random} \sim E(\text{MeanWS}) \]

where

\[ \text{random} \sim E(\text{mean}) \rightarrow \text{pdf}(x) = \lambda e^{-\lambda x}, \lambda = 1 / \text{mean} \]

If the generated size lies outside the range [MinWS, MaxWS], it is clipped to the nearest end of the range.

\[ \text{size} = \begin{cases} \text{MinWS} & \text{if size generated} < \text{MinWS} \\ \text{MaxWS} & \text{if size generated} > \text{MaxWS} \end{cases} \]
2.4 Event Spread

Starting at the initiation site, neighboring sites (both active and inactive) are added to the wind event until the combined area of the sites equals the event’s size. Wind spread is not dependent upon site conditions, including forest condition or the availability of active, foreasted sites. A wind event cannot spread to a site that belongs to another event that occurs at the same time step.

Neighboring sites are added dependent upon the wind speed (random $U(0, 1)$) and direction (randomly chosen from the 8 cardinal directions) for each wind event. A wind event can spread to nine (9) nearest neighbors. The relative location of the nine neighbors is dependent upon wind direction. In this example, the wind is from the west blowing to the east:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Source</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

The probability of spread to each neighbor type ($P_n$) is:

(A) Trailing neighbors. $P_n = \frac{(4 – \text{wind speed}) * (1 – \text{wind speed})}{8}$
(B) Lateral neighbors. $P_n = \frac{(4 – \text{wind speed})}{8}$
(C) Leading neighbors. $P_n = \frac{(4 – \text{wind speed}) * (1 + \text{wind speed})}{8}$
(D) Farthest neighbor. $P_n = \text{wind speed}$.

These probabilities are compared to a uniform random number:

$\text{random } U(0, 1) \text{ site} \leq P_n \Rightarrow \text{wind event spreads to neighbor}$

In this way, a high wind speed will create a more linear wind event shape; low wind speed will create a more round wind event shape.

2.5 Wind Damage

Wind damage is dependent upon the age of the cohorts at each site affected by an event. The oldest cohorts are most vulnerable. If a cohort is damaged by wind, the entire cohort is killed. The probability of a cohort being killed depends on its age. These data are user inputs (below).
Example of cohort age, mortality probability, and wind severity:

<table>
<thead>
<tr>
<th>Cohort Age (% of species longevity)</th>
<th>Probability of cohort mortality due to wind</th>
<th>Wind Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 20%</td>
<td>0.05</td>
<td>5</td>
</tr>
<tr>
<td>20% &lt; and ≤ 50%</td>
<td>0.10</td>
<td>4</td>
</tr>
<tr>
<td>50% &lt; and ≤ 70%</td>
<td>0.50</td>
<td>3</td>
</tr>
<tr>
<td>70% &lt; and ≤ 85%</td>
<td>0.85</td>
<td>2</td>
</tr>
<tr>
<td>95% &lt;</td>
<td>0.95</td>
<td>1</td>
</tr>
</tbody>
</table>

To determine if a cohort is killed, the wind mortality probability (WMP) is compared to the wind event intensity. If the event intensity is less than the WMP associated with the cohort’s age, then the cohort is killed.

Event Intensity < WMP[cohort’s age] → cohort killed

Each dead cohort has an associated wind severity based on its age (see table above). Wind severity describes the level of wind damage; a storm that kills more young cohorts is more severe. For each site in an event, the maximum wind severity is selected from the severities of all the site’s dead cohorts.

A wind event has an associated mean wind severity which is the average of the severities at all of the event’s sites.
3 Input Files Rules

The input rules for age-only succession are identical to those of the LANDIS-II Core Model. Please see the LANDIS-II Core User’s Guide for further instruction.

4 Input File Parameters

The first parameter is the title of the input file:

LandisData  “Wind Base”

The second parameter is the time step in years. For example:

Timestep  15

4.1 Wind Event Size and Frequency

Recall that sites with similar abiotic conditions are grouped into a single land type or ecoregion. Each ecoregion requires wind event parameters. These data are contained within a table. Each row corresponds to an ecoregion. The ecoregion names must match the names provided in the Ecoregion Input File (see LANDIS-II Core Users Guide). The ecoregion names need not be in any order nor do all of the ecoregion names need to be present. If an ecoregion is not listed, the default for all values is zero. An ecoregion may have no values because it represents a region of the landscape which does not have forested sites (for example, bodies of water, urban areas).

Next, there is one row per ecoregion. Each row contains the following data:

Table 1 – Wind Parameters for Ecoregions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>ecoregion name</td>
<td>string</td>
<td></td>
</tr>
<tr>
<td>maximum size</td>
<td>float</td>
<td>ha</td>
</tr>
<tr>
<td>mean size</td>
<td>float</td>
<td>ha</td>
</tr>
<tr>
<td>minimum size</td>
<td>float</td>
<td>ha</td>
</tr>
<tr>
<td>wind rotation period</td>
<td>integer</td>
<td>years</td>
</tr>
</tbody>
</table>
Here is an example of the WindEventParameters table:

```plaintext
>> Ecoregion  MaxSize  MeanSize  MinSize  EventProb
>> -------------------------------------------------------------
Eco3          400      24       4       100
Eco14         600      48       16      50
Eco10         400      24       4       75
Eco9          100      12       1       200
```

### 4.2 Wind Severity List

Next, a list describe wind severities and their associated cohort age ranges (% of species longevity) and probability of cohort mortality. **There can be one to many wind severities**, five has typically been used. For each severity, there is a range of relative cohort ages (% of species longevity) and a probability of cohort mortality. The expected data types are listed in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data Type</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>severity</td>
<td>integer</td>
<td></td>
</tr>
<tr>
<td>relative cohort age age range</td>
<td>{int} % to {int} %</td>
<td>% of cohort age [see format below]</td>
</tr>
<tr>
<td>cohort mortality probability</td>
<td>0 ≤ number ≤ 1</td>
<td></td>
</tr>
</tbody>
</table>

The following list was used in all previous versions of LANDIS:

```plaintext
>> Severity  % of longevity  Mortality
>> ---------  ------------------  --------
5           0% to 20%         0.05
4           20% to 50%       0.1
3           50% to 70%       0.5
2           70% to 85%       0.85
1           85% to 100%      0.95
```

### 4.3 Naming output files

Finally, two parameters configure the output files (see section 5) of the base wind extension. The first parameter, `MapNames`, provides the naming convention for the wind severity files. A macro, `{timestep}` is provided. **The user must indicate if the output should be placed in a sub-directory.** Also, the user must indicate the file extension. For example:
MapNames    wind/severity-{timestep}.gis

The next parameter, **LogFile**, indicates the file name and sub-directory for the single log output file. The file will be in ASCII comma delimited format. See section 5.2 for data included. Example:

LogFile    wind/log.csv
5 Output Files

The Wind Extension generates two types of output files: a) a map of wind severity for each time step, and b) a log of wind events for the entire scenario.

5.1 Wind Severity Map

The map of wind severity is labeled 0 for non-active sites, 1 for active and not disturbed sites, [wind severity + 1] for all disturbed sites. A map is produced for each wind time step.

5.2 Wind Event Log

The event log is a text file that contains information about every event over the course of the scenario: year, initiation cell coordinates, total event size (number of sites), number of damaged sites, number of cohorts killed total, mean wind severity across all sites.