LANDIS-II Base Wind v3.0

Extension User Guide

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1 Introduction

This document describes the **Base Wind** extension for the LANDIS-II model. For information about the model and its core concepts, see the *LANDIS-II Conceptual Model Description.*

The wind module described here generally follows the wind behavior as described in Scheller and Mladenoff (2004), with additional enhancements to allow variable shape and directional bias.

1.1 Wind Disturbances

During a wind time step, multiple wind events may occur on the landscape. Wind initiation and spread are not dependent upon forest condition.

1.2 Wind Rotation Period (WRP)

There is a probability of a storm initiating at each cell at each time step (the **Wind Event Probability** (WEP)):

$$WEP = \frac{Wind - Timestep(yrs) \times Cell - Area(ha)}{WRP \times Mean - Wind - Size(ha)} \qquad (1)$$

WRPs are generally estimated from historic data of wind disturbance size and frequency. Note that many historic records include only catastrophic wind events whereas this wind extension simulates all wind events, including very light and moderate intensity wind events.

A 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:

$$\text{random}_{U}(0, 1)_{\text{site}} \leq \text{WEP}_{\text{site's ecoregion}} \rightarrow \text{wind event starts}$$

1.3 Event Intensity

Each wind event has an intensity that is related to mean wind speed. The intensity value is drawn from a uniform random distribution, scaled from 0.0 to 1.0: $\text{random}_{U}(0, 1)$. An intensity of 1.0 represents the highest wind speed that could be expected to occur in the ecoregion. An intensity of 0.0

represents the greatest wind speed that all species cohorts can survive (i.e., that does not kill any cohorts).

1.4 Event Size

Each wind event has a size (units: hectares) that is calculated from the 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 wind event size is a random number generated using a negative exponential distribution whose mean is MeanWS.

$$size_{generated} = random_{E}(MeanWS)$$

where

$$random_{E}(mean) \rightarrow pdf(x) = \lambda e^{-x\lambda}, \lambda = 1 / mean$$

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

$$size = \begin{cases} MinWS & \text{if } size_{generated} < MinWS \\ MaxWS & \text{if } size_{generated} > MaxWS \\ size_{generated} & \text{otherwise} \end{cases}$$

1.5 Event Elongation

Each wind event has a length-to-breadth ratio drawn from a user-defined normal distribution. The specified mean and standard deviation define the distribution. If the standard deviation is 0, all events will have a length-to-breadth ratio equal to the mean. Behavior of previous versions of the Base Wind extension can be replicated by setting mean = 1 and standard deviation = 0.

1.6 Event Direction

Each wind event has a predominant spread direction, which is one of the 8 cardinal directions (i.e., N, NE, E, SE, S, SW, W, NW). Because the actual direction of spread has no bearing on the event, the opposite directions are

treated equivalently. For example, and wind event with a spread direction of N, will have the same resulting direction as an event with a spread direction of S. Therefore, the user defines the percentage of wind events that should have each of the 4 main directional paths (i.e., N-S, NE-SW, E-W, NW-SE). For each wind event, a direction is randomly drawn with the probability of choosing each direction determined by the provided percentages. Behavior of previous versions of Base Wind (random direction) can be replicated by setting all four percentages to 25%.

1.7 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 the species or cohorts found on a site. A wind event cannot spread to a site that belongs to another wind event that occurs at the same time step.

Neighboring sites within a wind event are added dependent upon wind intensity (1.3) and direction (1.6) and length-to-width ratio (LWratio; 1.5). A wind event can spread to ten (10) nearest neighbors. The relative location of the ten neighbors is dependent upon wind direction. In this example, the wind is from the west blowing East-West:

	B	A	B	
D	C	Source	C	D
	B	A	B	

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

(A) Lateral neighbors. P_n =[1/(LWratio * 2)]

(B) Diagonal neighbors. P_n = [1/LWRatio]

(C) Leading neighbors. P_n = [1]

(D) Farthest neighbor. P_n = intensity.

These probabilities are compared to a uniform random number:

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

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

1.8 Wind Damage

Wind damage at each site affected by an event is dependent upon the age of the cohorts (relative to species longevity) and wind intensity (speed). The oldest cohorts are more vulnerable than younger cohorts. If a cohort is damaged by wind, the entire cohort is killed.

Wind severity is a classification variable that is written to the wind severity output maps. It is not to be confused with wind intensity. The wind severity table specifies the relationship between wind intensity and cohort mortality, and assigns a wind severity label to each level of mortality. The following is an example of a wind severity table:

Relative Cohort Age (% of species longevity)	**Wind Mortality Probability (WMP)**	**Wind Severity**
≤ 20%	0.05	5
20% < and ≤ 50%	0.10	4
50% < and ≤ 70%	0.50	3
70% < and ≤ 85%	0.85	2
95% <	0.95	1

The probability of a cohort being killed depends on its relative age (% of species longevity) and wind intensity. To determine if a cohort is killed, the wind mortality probability (WMP) associated with the cohort's relative age in the wind severity table is compared to the wind event intensity, which ranges from 0.0 – 1.0. If the intensity is **greater than** one minus the WMP associated with the cohort's relative age, then the cohort is killed.

Event Intensity > (1 - WMP[cohort's age]) → cohort killed

Each dead cohort has an associated wind severity value based on its age (see table above). Wind severity indicates the level of wind damage; more severe storms kill younger cohorts. 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. **Wind severity is calculated only for use in the wind output maps.**

1.9 Major Releases

1.9.1 V3.0

Base Wind now allows the user to define the distribution of wind event shapes (length-to-width ratio) and the distribution of wind directions.

1.9.2 v2.1

Base Wind is now more fully compatible with v6.0. More significantly, the meta-data library was added for the creation and auto-documentation of outputs, both for the maps and for the event log.

1.9.3 v2.0

Base Wind was converted to be compatible with LANDIS-II v6.0.

1.9.4 v1.2

The differences between version 1.2 and the previous version (1.1) include fixing a bug that caused high intensity events to be round and low intensity events to be ellipses, the opposite of what you would expect.

1.10 Minor Releases

1.11 References

Scheller, R. M. and Mladenoff, D. J. A forest growth and biomass module for a landscape simulation model, LANDIS: Design, validation, and application. Ecological Modelling. 2004; 180(1):211-229.

1.12 Acknowledgements

Funding for the development of LANDIS-II has been provided by the Northern 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 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 Example File

```
LandisData  "Base Wind"

Timestep  15

LWRatioMean  3.0
LWRatioStDev 0.5

WindDirectionTable
>> Percent  Direction
>> -------  ---------
     0      << N-S
     25     << NE-SW
     50     << E-W
     25     << SE-NW

EcoregionTable
>>                                Wind
>>             Max   Mean  Min   Rotation
>> Ecoregion   Size  Size  Size  Period
>> ---------   ----  ----  ----  --------
   Eco3         400    24     4     100
   Eco14        600    48    16      50
   Eco10        400    24     4      75
   Eco9         100    12     1     200


WindSeverities
>>            Cohort Age       Mortality
>> Severity   % of longevity   Probability
>> --------   --------------   -----------
       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
```

```
MapNames  wind/severity-{timestep}.img
LogFile   wind/log.csv
```

2.2 LandisData

This value of this parameter must be "Base Wind".

2.3 Timestep

This parameter is the timestep of the wind extension. Value: integer > 0. Units: years.

2.4 LWRatioMean

The keyword LWRatioMean is followed by the value for the mean length-to-breadth ratio. The mean, along with the standard deviation, define the normal distribution from which event length-to-width ratios are drawn. Value: decimal > 0. Units: ratio.

2.5 LWRatioStDev

The keyword LWRatioStDev is followed by the value for the standard deviation of length-to-breadth ratios. The standard deviation, along with the mean, define the normal distribution from which event length-to-width ratios are drawn. Value: decimal. Units: ratio.

2.6 WindDirectionTable

The keyword WindDirectionTable precedes the table of wind direction percentages. The following four lines define the percentage of events with primary directions of N-S, NE-SW, E-W, SE-NW, respectively. The listed percentages must sum to 100%. The directional bias of wind events will approximate the directional percentages provided in this table. Value: percentage (0 – 100). Units: %.

2.7 Ecoregion Parameter Table

The keyword EcoregionTable precedes the table of parameters that control the size and frequency of wind events by ecoregion. Each row in the table contains the parameters for one ecoregion.

2.7.1 Ecoregion Column

The first column in the table contains ecoregion names. Each name must be defined in the ecoregions input file (see chapter 6 Ecoregions in the LANDIS-II Model User Guide). The ecoregion names can be in any order and not all of the ecoregion names need to be present. If an ecoregion is not listed, all the parameters for that ecoregion are assigned the default value of zero.

2.7.2 Max Size

This parameter is the maximum size of wind events in the ecoregion. Value: decimal number ≥ Min Size. Units: hectares.

2.7.3 Mean Size

This parameter is the mean size of wind events in the ecoregion. Value: decimal number between Min Size and Max Size. Units: hectares.

2.7.4 Min Size

This parameter is the minimum size of wind events in the ecoregion. Value: decimal number ≥ 0.0 Units: hectares.

2.7.5 Wind Rotation Period

This parameter is the average wind rotation period for the ecoregion. Wind rotation is the average time needed to disturb a cumulative area equal to the size of the study area. Value: integer ≥ 0. Units: years.

2.8 Wind Severity Table

This table defines wind severities by associating cohort mortality probabilities with wind intensity (speed). There can be one or more wind severities; five has typically been used. The values shown in the example file (see section 2.1) are those used in previous implementations of the LANDIS model.

2.8.1 Table Name

The keyword for the table is "WindSeverities".

2.8.2 Cohort Age

This parameter specifies the range of relative cohort ages with a common Wind Mortality Probability. Relative cohort ages are given as a percentage

of species longevity, and the range is expressed as “lower bound to upper bound”. The relative age is applied to all species and it is not possible to differentiate WMP by species. Valid values for both lower and upper bounds: 0% ≤ integer ≤ 100%. Units: Percentage of species’ longevity.

2.8.3 Mortality Probability

This parameter is the minimum wind intensity value that will kill the cohorts given in the Cohort Age column. Value: 0.0 ≤ decimal number ≤ 1.0

2.8.4 Severity Column

The severities must appear in decreasing order in the table, with zero representing the least severe wind event. Value: integer ≥ 0. Units: years.

2.9 MapNames

This file parameter is the template for the names of the wind severity output maps (see section 3.1). 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 the file extension. The user must also include sub-directory name(s) as needed.

2.10 LogFile

The file parameter is the name of the extension’s event log file (see section 3.2).

3 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.

3.1 Wind Severity Maps

The map of wind severity uses a code of 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.

3.2 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, event intensity, event wind direction, event length-to-width ratio, total event size (number of sites), number of damaged sites, number of cohorts killed total, mean wind severity across all sites. The information is stored as comma-separated values (CSV).