LANDIS-II Base Wind v2.2

Extension User Guide

Robert M. Scheller, North Carolina State University
James B. Domingo

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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 follows the wind behavior as described in Scheller and Mladenoff (2004).

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:

random U(0, 1) site ≤ WEP site's ecoregion → wind event starts

1.3 Event Intensity

Each wind event has an intensity that is inversely related to mean wind speed. The intensity value is drawn from a uniform random

distribution, scaled from 0.0 to 1.0: random U(0, 1). An intensity of 0.0 represents the highest wind speed that could be expected to occur in the ecoregion. An intensity of 1.0 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) → pdf (x) = λ e-x λ, λ = 1 / mean

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

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

1.5 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 and direction (randomly chosen from the 8 cardinal directions). 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:

A	B	C	
A	Source	C	D
A	B	C	

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

(A) Trailing neighbors. Pn = [(4 – wind speed) / 8 * (1 – wind speed)]

(B) Lateral neighbors. Pn = [(4 – wind speed) / 8]

(C) Leading neighbors. Pn = [(4 – wind speed) / 8 * (1 + wind speed)]

(D) Farthest neighbor. Pn = wind speed.

These probabilities are compared to a uniform random number:

random U(0, 1) site $\leq$ Pn $\rightarrow$ 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.

1.6 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 **less than** the WMP associated with the cohort's relative age, then the cohort is killed.

Event Intensity < 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.**

1.7 Major Releases

1.7.1 Version 2.2 (June 2017)

Added compatibility with the Metadata library. The Metadata Library outputs metadata for all model outputs, allowing compatibility with visualization tools.

1.7.2 Version 2.1

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.

1.7.3 Version 2.0

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

1.7.4 Version 1.2

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.

1.8 Minor Releases

1.9 References

Mladenoff, David J., and Hong S. He. "Design, behavior and application of LANDIS, an object-oriented model of forest landscape disturbance and succession." Spatial modeling of forest landscape change: approaches and applications. Cambridge University Press, Cambridge, UK (1999): 125-162.

1.10 Acknowledgements

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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 LandisData

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

2.2 Timestep

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

2.3 Wind Event Parameter Table

The parameters in this table control the size and frequency of wind events. The parameters are ecoregion-dependent. Each row in the table contains the parameters for one ecoregion.

2.3.1 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.

2.3.2 Max Size

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

2.3.3 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.

2.3.4 Min Size

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

2.3.5 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.

2.4 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.

2.4.1 Table Name

The keyword for the table is "WindSeverities".

2.4.2 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.

2.4.3 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

2.4.4 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.

2.5 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.

2.6 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, 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).

4 Example File

```
LandisData  “Base Wind”

Timestep  15

>> Wind Event Parameters
>>                              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
```