Technical Report: LANDIS-II double exponential seed dispersal algorithm

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The purpose of this document is to provide a technical overview of the double exponential seed dispersal algorithm developed by Brendan Ward and Robert Scheller. This document will be available to all registered LANDIS-II Users. The source code will be available to all registered LANDIS-II Developers.

The double exponential seed dispersal algorithm determines the probability of parent tree (a mature species-age cohort) seeds reaching another site (or cell) on the modeled landscape. The seed dispersal probability curve is defined by two dispersal distance parameters: effective distance and maximum distance (He and Mladenoff 1999). The effective distance defines the farthest distance that 95% of the seed rain will reach in any direction away from the parent cohort. The maximum distance defines the farthest distance for the remaining 5% of the seed rain. This algorithm replaces the previous dispersal algorithm (He and Mladenoff 1999) with a two-part exponential probability distribution, drawing from the exponential dispersal kernels presented by Clark et al. (Clark et al. 1998) (Equation 1). A special situation arises when using grid cell sizes that exceed the effective dispersal distance (Equation 2).

This distribution function was designed to: more accurately represent long-distance seed dispersal; model seed dispersal probability from the outer edge of the source site rather than the centroid; be robust with respect to the map resolution used within LANDIS-II; and fulfill the requirements of a probability distribution (e.g., probabilities sum to 1.0). In particular, the algorithm removes the previous bias where the sum of the probabilities for long-distance dispersers was greater than the sum of the probabilities for shorter-distance dispersers. In addition, the probabilities consistently sum to one for any cardinal direction away from the cell of interest, regardless of resolution, removing a bias that significantly inflated probabilities for landscapes with small (< 100 m) resolutions. The algorithm does not explicitly account for volume of seed rain. However, if there are multiple cells containing parent cohorts within the maximum distance radius, the total probability will be equal to the sum of the probabilities for each source cell.

We tested the seed dispersal algorithm for internal logic and consistency using linear plots of seed dispersal probability as a function of effective and maximum distance (Figure 1); raster grids of dispersal probability from a single seed source for each tree species included in our model runs; and 200 - 300 year long LANDIS-II simulations (Ward et al. *In Review*, Scheller and Mladenoff *In Review*).

Reference List

Clark, J. S., C. Fastie, G. Hurtt, S. T. Jackson, C. Johnson, G. A. King, M. Lewis, J. Lynch, S. W. Pacala, C. Prentice, E. W. Schupp, T. Webb III, and P. Wyckoff. 1998. Reid's paradox of rapid plant migration. Bioscience **48**: 13-24.

He, H. S. and D. J. Mladenoff. 1999. The effects of seed dispersal on the simulation of long-term forest landscape change. Ecosystems **2**: 308-319.

Scheller, R. M. and D. J. Mladenoff. *In Review*. Estimating the effects of climate change, species distributions, and disturbance on forest composition and biomass in northern Wisconsin, USA. Global Change Biology .

Ward, B. C., D. J. Mladenoff, and R. M. Scheller. *In Review*. Landscape-level effects of the interaction between residential development and public forest management in northern Wisconsin, USA. Forest Science .

$$\mathbf{P} = e^{(x - cellsize)*\left(\frac{\ln(1-k)}{EffDist}\right)} - e^{(x)*\left(\frac{\ln(1-k)}{EffDist}\right)}$$

for $x \in [cellsize, EffDist]$ and *cellsize* <= *EffDist*

and:

$$\mathbf{P} = (1-k)*e^{(x - cellsize - EffDist)*\left(\frac{\ln(b)}{MaxDist}\right)} - (1-k)*e^{(x - EffDist)*\left(\frac{\ln(b)}{MaxDist}\right)}$$

for $x \in [EffDist, MaxDist]$ and *cellsize* <= *EffDist*

Equation 1: Two-part negative exponential probability distribution for seed dispersal when the grid cell size is less than the effective distance of a given species. *x* is the centroid-to-centroid distance from the source site to the current site, *cellsize* is the grid cell size of the simulation (e.g., 25 meters), *EffDist* is the effective distance, *MaxDist* is the maximum distance, *k* is the probability that seed will disperse within the effective distance (e.g., 0.95), and *b* is a calibration coefficient (set to 0.01 here).

$$\mathbf{P} = e^{(x-cellsize)*\left(\frac{\ln(1-k)}{EffDist}\right)} - (1-k)*e^{(x-EffDist)*\left(\frac{\ln(b)}{MaxDist}\right)}$$

for $x = cellsize$ and $cellsize > EffDist$

and:

$$\mathbf{P} = (1-k)*e^{(x-cellsize-EffDist)*\left(\frac{\ln(b)}{MaxDist}\right)} - (1-k)*e^{(x-EffDist)*\left(\frac{\ln(b)}{MaxDist}\right)}$$

for $x \in [cellsize, MaxDist]$ and $cellsize > EffDist$

Equation 2: Two-part negative exponential probability distribution for seed dispersal when the grid cell size is greater than the effective distance of a given species. *x* is the centroid-to-centroid distance from the source site to the current site, *cellsize* is the grid cell size of the simulation (e.g., 25 meters), *EffDist* is the effective distance, *MaxDist* is the maximum distance, *k* is the probability that seed will disperse within the effective distance (e.g., 0.95), and *b* is a calibration coefficient (set to 0.01 here).

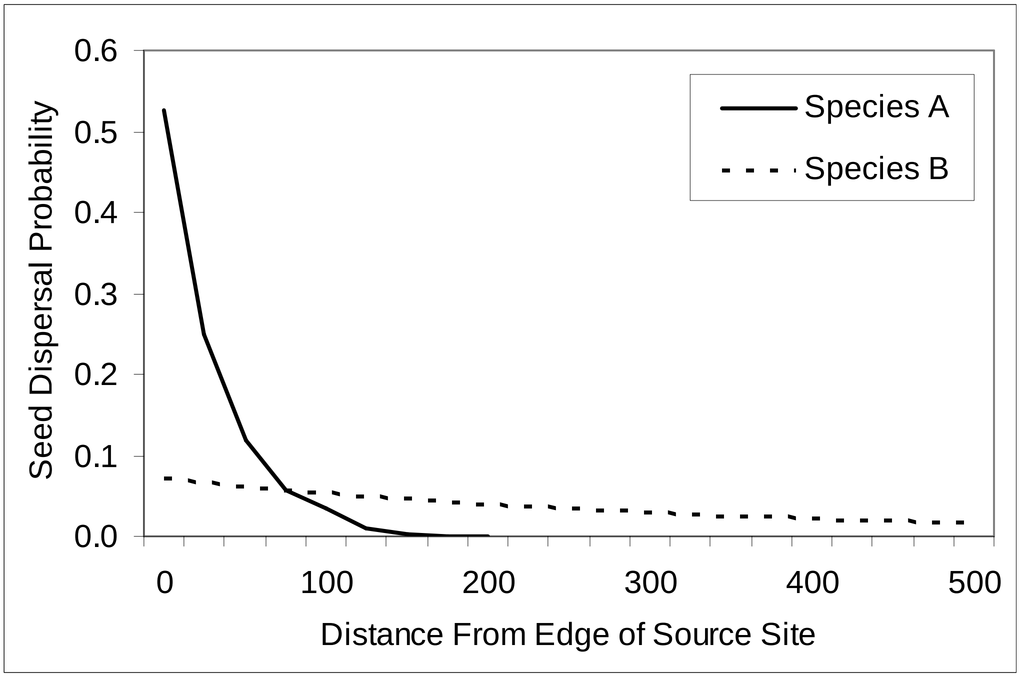

Figure 1: Exponential probability distribution of seed dispersal for two hypothetical tree species based on a map resolution of 25 units. Species A: *EffDist*=100 units, *MaxDist*=200 units (e.g., sugar maple); Species B: *EffDist*=1000 units, *MaxDist*=5000 units (e.g., aspen). Horizontal axis truncated for clarity.