LANDIS-II

Root rot disturbance extension

In the limited literature on the factors that determine *Phytophthora cinnamomi* presence and impact, it appears that temperature and soil moisture are the primary limiting factors. The presence of preferred hosts also seem to have some effect. Other factors that are of lesser importance (at least in Spain) and probably more difficult for us to model include abundance of agriculture within a 1 km cell, soil pH, NDVI within a 1 km cell. It appears to be assumed in the literature that dispersal of the fungus to a site is not limiting (i.e., we can assume propagules are ubiquitous).

Based on this, I have drafted a crude but perhaps feasible LANDIS-II disturbance extension that may be realistic enough to simulate the landscape-level effects of root rot in eastern US forests. The extension would typically run at an annual or decadal time step, removing biomass of host cohorts as a function of the likelihood that *P. cinnamomi* is present and the relative susceptibility of tree species to root rot. The extension would model 2 primary processes on each grid cell: 1) the probability of *P. cinnamomi* presence on the cell and 2) damage to each cohort, relative to its susceptibility to *P. cinnamomi*.

**1) *P. cinnamomi* presence**

Probability of presence of *P. cinnamomi* is a function of 3 limiting factors, computed using state variables carried by PnET-Succession.

ProbPresence = dTemp \* dWater \* dHosts. dTemp is a temperature limiting factor, dWater is a soil water limiting factor, and dHosts is a host-induced limiting factor (assumes presence of hosts increases the likelihood that *P. cinnamomi* will occur).

dTemp = (AnnTmin - LethalTemp) / ABS(LethalTemp); where AnnTmin=mean annual extreme minimum temperature during the last time step, and LethalTemp=minimum temperature below which *P. cinnamomi* cannot survive. From McConnell and Balci (2014), this may be about -24 oC (*P. cinnamomi* unable to survive in USDA hardiness zone 6 or higher). Function currently assumes dTemp=1.0 at >=0 oC, so LethalTemp must be <0. Constrain dTemp to range between 0 and 1. AnnTmin (temperature extreme) may need to be computed from Tmin using the algorithms we are testing for ColdTolerance mortality of tree cohorts. If cold is not limiting to *P. cinnamomi* except by mortality, then dTemp should =1 above LethalTemp and =0 below LethalTemp.

dWater = 1 - (ph / phThresh); where ph=mean growing season pressure head (water potential) during the last PnET-Succession time step, and phThresh=minimum water potential need to support *P. cinnamomi.* Note that ph within PnET-Succession is a function of precipitation, soil texture, evaporation and transpiration by cohorts, and it is dynamic, directly reflecting monthly water conditions in the soil. This is perhaps the most powerful feature of this algorithm.

dHosts =  HostBM /  AllSppBM; where  HostBM is the sum of the biomass of each host species, and  AllSppBM is the sum of the biomass of all species on the cell. Perhaps this should be constrained to cells with total biomass greater than some amount (e.g., 5000 g/m2), which assumes that there needs to be sufficient presence of trees to act as an attractor of the fungus. This constraint could serve as a tuning parameter for the dHosts factor. The definition of host v. non-host would be determined by their susceptibility index parameter (see below), with the user defining the threshold value to determine if the species is a host for the purpose of this calculation. Alternatively, the HostBM sum could simply be the sum of all cohorts, weighted by susceptibility, which would eliminate an input parameter.

Presence is stochastically computed by comparing ProbPresence to a uniform random deviate.

**2) Damage to cohort of species *i***

It is not completely clear to me what the impact of *P. cinnamomi* is on trees. What follows is based on my assumption that the fungus ultimately kills trees in proportion to their susceptibility to the fungus, rather than reducing productivity (net photosynthesis). Damage would range from complete mortality of a cohort (complete elimination of its live biomass) to mortality of only a few individuals (small reduction in cohort live biomass). Although I understand that infections can initially reduce the ability of individuals to photosynthesize (by choking off water supply to leaves), the primary impact on landscape-scale biomass and composition of forests is assumed to be related to mortality, which is usually our primary interest when using the LANDIS model. Thus, I am ignoring the photosynthesis reductions that precede death. Let me know it this is unrealistic.

Damage(*i*) = Presence \* Susceptibility(*i*); where Damage(*i*)is the proportion of cohort biomass removed, and Susceptibility(*i*) is an index of susceptibility of species *i*, ranging from 0.0 – 1.0, where 1.0 is completely susceptible.

Note that the functions are linear. It may be appropriate to compute some of the limiting factors to make them non-linear. If the answers are not in the literature, we’ll have to rely on expert opinion.

This algorithm would likely require some modification of PnET-Succession to compute the mean temperature and water variables needed by the extension and pass them to the extension. This extension would not work with Biomass Succession or Age-only Succession, but perhaps could be compatible with NECN Succession.

**References**

Hernández-Lambraño [RE](https://www.sciencedirect.com/science/article/pii/S0378112717305558#!) , [González-Moreno](https://www.sciencedirect.com/science/article/pii/S0378112717305558#!) P, [Sánchez-Agudo](https://www.sciencedirect.com/science/article/pii/S0378112717305558#!) JÁ (2018) Environmental factors associated with the spatial distribution of invasive plant pathogens in the Iberian Peninsula: the case of *Phytophthora cinnamomi* Rands. [Forest Ecology and Management](https://www.sciencedirect.com/science/journal/03781127) 419-421:101-109.

McConnell ME, Balci Y (2014) *Phytophthora cinnamomi* as a contributor to white oak decline in mid-Atlantic United States forests. Plant Disease 98:319-327.