Laboratory # 10: Forest Succession and Land-Use History

Introduction

The species composition of a forest can be influenced by many factors including the elapsed time since the last disturbance, type of disturbance (e.g. agriculture, wind storms, logging, tires), site soil characteristics, herbivory, and microclimate. In this exercise, we will use a simple model of forest succession (or dynamics) to explore the consequences of land use history on the dynamics of change in forest stands. Our predictive model will be based on the relationship between existing canopy trees and their most likely replacements (Horn 1975).

Succession is the set of changes in a collection of species in a given location over time. Community ecologists are interested in predicting the dynamics of different communities (e.g. how species composition and community structure changes) and understanding the processes that drive the dynamics. In a forest, such processes can include species-specific differences in: sapling mortality, susceptibility to herbivores or pathogens, lifespan, growth responses to changing light or nutrient conditions, recruitment and dispersal characteristics, germination requirements, and reproductive output, among other factors.

In this study, we will focus on the replacement processes that occur within established forest stands, by examining the relationship between canopy tree species and individuals likely to replace them. In many cases, a near-by sapling or understory tree is likely to replace an adult tree that dies. The ultimate replacement depends upon many factors including the relative height growth rates of the saplings in the area, their position (and thus exposure to sunlight) in the gap, and their abilities to withstand periods of suppressed growth in the understory. This process is called gap phase dynamics. The extent to which replacement trees are different species will indicate the extent to which the forest will change over time. We will identify likely replacements for several adult tree species and integrate this information with a Markov model to predict future “states” of the forest.

Markov models are largely based on probabilities of transition from one state to another. Let’s look at a simple example: say a forest stand is composed of 10 oaks and 5 hemlocks. Further, 60% of
the oaks are replaced by hemlocks when they die and 40% by oaks. Eighty percent of the hemlocks are replaced by hemlocks and 20% by oaks. What is the canopy composition of the next generation?

- The oaks in generation 2 = (10 current oaks * 0.4) + (5 hemlocks * 0.2) = 4 + 1 = 5 oaks.
- The hemlocks in generation 2 = (10 current oaks * 0.6) + (5 hemlocks * 0.8) = 6 + 4 = 10 hemlocks.

This is the basis of a simple Markov model that can be iterated for any number of generations to predict forest canopy composition at any point in time.

Some simplifying assumptions are required to model a complicated system such as forest succession requires - complexities can be added later as needed. The simplifying assumptions of the Markov model are:

1. The total number of trees in the forest will remain constant; as a tree dies, it is replaced by one tree.
2. All trees live for one generation and die at approximately the same age.
3. No new species will invade the stand.
4. The probabilities of replacement for each species are constants and will not change through time or space.

Methods

Field

1. To develop our model of forest succession, we need to first categorize trees as “canopy” trees or “replacement” (understory) trees. I suggest using a DBH cutoff of 20 cm, but feel free to develop your own criteria as a class (NOTE: Wednesday’s lab section will need to follow the criteria established by Tuesday's lab section). You’ll also probably want a minimum DBH cutoff as well to exclude very small saplings.

2. For each canopy tree, we need to identify likely replacements. You have two at least two options for identifying replacement trees. Again, decide which protocol you want to use as a class, but keep in mind that the Wednesday section will be stuck with what the Tuesday section has decided! You can:
   a. Count up all “replacement” trees under the canopy of the “canopy” tree. Each of these replacement trees is equally likely to replace the canopy tree.
   b. Based on the position and size of all replacement trees under the canopy of the “canopy” tree, pick a single tree that you predict will replace the canopy tree.

3. In your data sheet, record the species of canopy tree and the species of the replacement tree(s).