Climate Change Rapidly Threatening Northeastern Forest Ecosystem Tree Species

Lucien Aime Theriault - Department of Geography and Forestry, University of Vermont, Burlington VT, USA - Lucien.Theriault@uvm.edu

Major Ecological Information 1

Since the Industrial Revolution, atmospheric carbon dioxide levels have been rising exponentially and are uncontrolled. Precipitation and corresponding moisture availability are the greatest limiting factors on tree growth (Martin-Benito, et al., 2015). Longer growing seasons, due to rising annual temperatures, are affecting the water balance and drought sensitivity of ecosystems (Harrison., 2020). Additionally, land-use history and management practices such as the global timber industry, are responsible for the large-scale spread of invasive pests and pathogens. These factors are causing increased forest mortality and tree species distribution migration (*Figure 1*) (Allen, et al., 2010).

Major Ecological Information 2

Understanding the ways climate change is altering the functioning of forests is crucial in interpreting the significant mechanisms of tree species range movement. Increasing drought stress sensitivity and drought induced tree mortality are disproportionately affecting the southern extent of tree species ranges. As annual temperatures have risen, the growing season of tree species has elongated. Earlier growing seasons have been correlated with an increase in water consumption and deficits in the yearly ecosystem water balance (D'orangeville, et al., 2018). Drought stress causes a reduction of xylem functioning capacity severely during the drought period and moderately in the recovery years that follow (*Figure 2*). Farther south, where the growing season is longer, the forest drought sensitivity is higher. The southern extent of tree species are more resistant to drought stress than the northern extent, but are far less resilient during recovery years (Calvin, et al., 2017). This means that latitudinally, the southern extent of tree species ranges are more susceptible to damage and death after multi-year and seasonal droughts. Forest mortality is a natural disturbance that opens space for new growth in the forest ecosystem. Due to competition, tree species will occupy the ecological niche where they are able to out-compete all other species. Under these new conditions, species from less diverse northern regions will have to compete with a greater number of southern species that will be better able to compete and occupy northern niches (*Figure 1*) (Pan, et al., 2018).

Ecological Overview

Anthropogenic climate change, along with land use and management practices, is having profound impacts on forested ecosystems. Altered climate variables such as temperature and precipitation are affecting the success of tree growth, and land management practices are causing an increase in destructive natural disturbance regimes. These factors are drastically changing the diversity, distribution, and health of forest ecosystems in New England. This study investigates how climate change will affect the distribution of dominant tree species in New England's hardwood forests. Understanding forest composition changes is critically important for ecologists and forest specialists to be able to make management decisions that will protect wildlife and ecosystems as a whole, while contending with the effects of climate change.

Experimental Design and Methods

This research proposal is for the mapping and modeling of northeastern New England forests' ecosystem composition and structure. Over the temporal period of fifty years, at intervals of every two years, the spatial range covering the states Maine, Vermont, and New Hampshire will be mapped using the same methods. Further, research will be conducted at the same biannual interval to investigate tree species functional response to drought stress.

The mapping of this region will be conducted using aerial LiDAR remote sensing technology in order to gather data about individual tree species ranges, and forest stand structure. Tree drought stress responses will be monitored by observing functional xylem tissue cross sections under a epifluorescence light microscope (*Figure 2*), gathered from northern deciduous hardwood tree species, and collected by random sampling of the landscape. The remote sensing data will be used to model changes in tree species distribution and ecosystem dominance.

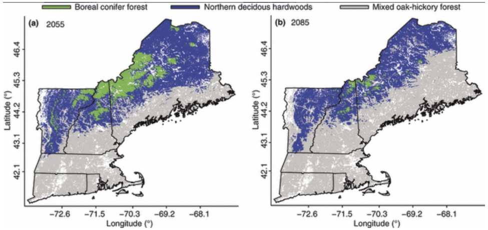

Figure 1. Modeled distribution of mixed oak-hickory, northern deciduous, and boreal forests in New England for future climate model predictions.

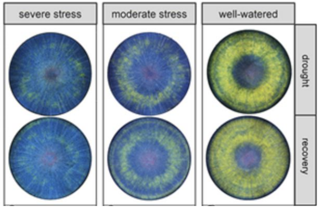

Figure 2. Xylem cross sections of American Beech saplings with well-watered, moderate drought stress, and severe drought stress scenarios. Functional xylem tissue was dyed yellow and observed under a epifluorescence light microscope. The comparison shows the functional difference between moisture availability for each scenario and the moderate lasting effects of drought on functional xylem.

Objectives

1. Understand the mechanisms of tree species' distribution and function and how they will change due to current and projected climatic conditions and land management.
2. Model the changing ranges of tree species with forest composition and structure data over half a century.
3. Gather tree xylem function data in order to understand individual tree species drought stress responses both latitudinally and over time.

Hypothesis

Based on the findings of previous studies, it is hypothesized that changing climate variables will force tree species to experience a shift northward as they become less well suited to compete in the southern extent of their range and better suited to compete north of their range. Additionally, as moisture availability decreases, tree function will decrease, while functional resistance to drought stress and recovery resilience will increase over time.

Literature Cited: Allen, C. D., et al. (2010). *Forest Ecology and Management, 259*(4). - Calvin, Liam, and Alistair S Jump. (2017). *Global Change Biology*, 23(1), 362–379. - D'orangeville, L., et al. (2018). *Global Change Biology, 24*(6), 2339-2351. - Harrison, Jamie L. (2020). *Ecological Society of America*, 101(11). - Martin-Benito, D., & Pederson, N. (2015). *Journal of Biogeography, 42*(5), 925-937. - Pan, Yude, et al. (2018). *Forest Ecosystems*, 5(1).