ANNUAL REPORT
Northeastern Regional Center of the Department of Energy's National Institute for Climatic Change Research

PROJECT TITLE:
Northeastern forest regeneration in a warmer and wetter climate

PRINCIPAL INVESTIGATOR:
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PROJECT DURATION:
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1. Abstract

Northeastern forest composition has been predicted by models to change dramatically in response to forcasted changes in climate. We are undertaking a field experiment to measure tree species reponses to a warmer and wetter climate. To do this we simulate predicted climate change with warmed (~2^{o}C) and irrigated (~20%) field plots in a recently harvested forest of central Pennsylvania. In the treatment plots we measure tree germination and seedling growth, as well a plant physiology, morphology, and phenology and soil pools and processes. We hypothesize that simulated climate change will differentially affect species' success in the seedling stage, therefore supporting or refuting model predictions of forest composition changes.

The warming and irrigation treatments have been underway since March, 2008 and thus far we have seen earlier mean tree seedling germination dates in warmed and warmed+irrigated plots than irrigated and control plots. The pattern is most notable among the oak species, indicating that the warming treatment is already giving oak seedlings a growth advantage. We will continue monitoring seedling germination, growth, gas exchange, and foliar and soil biogeochemistry for the remainder of this growing season and the following two years.

2. Research highlights (as appropriate).

The experimental heating and irrigation treatments have been underway for only 5 months, therefore research highlights at this time pertain to efficacy of the experimental treatments of heating and irrigation. For example, a few days after the infrared heating lamps were turned on there was a noticeable melt off of snow in the plots (Figure 1). Surface and soil temperatures are warmer in heated than unheated plots (Figure 2).

3. Research products (as appropriate).

No project-related data, models, or other research products are available yet.

4. Publications (required).

No project-based publications have been produced yet.

5. Student degrees supported (as appropriate).

The following students have completed the first year of their graduate programs and are being supported in part of full by this project:
Rebekah Wagner, PhD. Tentative thesis title: Physiological responses of tree seedlings to experimental warming and irrigation.

Marshall McDaniel, PhD. Tentative thesis title: Soil processes and belowground community responses to experimental warming and irrigation.

6. Technical report

Overview

Models of tree responses to climate change predict dramatic shifts in northeastern forest species composition that have not been corroborated by experimental climate change manipulations. **Our main objective is to provide a field-based test of predictions of forest species composition shifts using *in situ* warming and irrigation.** Our experimental manipulations impose predicted climate conditions for the northeastern US on a post-harvest, regenerating forest to ask the question: are germination and seedling responses to climate manipulation consistent with model predictions of shifts in tree species in a warmer and wetter climate? During the first year of the project we spent six months on site preparation and construction of the heating and irrigation system. We are currently in the middle of the first growing season and have been measuring seedling germination, growth, and gas exchange, as well as soil gas exchange and nutrient availability.

Experimental Set Up

The first six month of the project focused on site preparation and construction of the heating and irrigation systems. In summer 2007, overstory and understory vegetation and soils were sampled prior to any manipulations of the research area. In September 2007 a 6-ha area of second-growth, mixed-deciduous forest was harvested and surrounded by deer-exclosure fencing. The local electricity provider was contracted to install a tranfer box at the site, and electricity was delivered to the site by January 2008. Concurrently, 16 2X4m research plots in 4 blocks were established within the cut and fenced area. Kalglo infrared heating lamps were installed (2 per plot) in 8 of the 16 plots (Fig. 1) and infrared thermometers were suspended above all plots to measure ambient temperatures. The lamps and thermometers were attached to a datalogger and Bruce Kimball, a senior research associate at the USDA lab in Maricopa, AZ, was consulted for programming of the datalogger. The datalogger was programmed to keep the heated plots at a constant differential from the ambient plots of 1^{o} C during the day and 3^{o} C at night. Eight of the 16 sites were selected for irrigation, creating four treatment regimes: heated, irrigated, heated+irrigated, and ambient; N=4. We calculated the long-term monthly mean precipitation with data from 1880-2000 from a weather station in State College, PA (approximately 15 km away; data downloaded from the US Historical Climatology Network, http://cdiac.ornl.gov/epubs/ndp/ushcn/newushcn.html). Five precipitation catchments were constructed in the study area to collect rain water for plot irrigation. Irrigated plots are watered once a week with a volume of water that equals 20% of the long-term mean (Table 1). Beginning in March 2008, air and soil temperature and soil moisture have been monitored in all plots (Fig 2).

One of the objectives of our study is to observe how both native and southern tree species respond to simulated climate change. To do this we manipulated the seedbank in half the area of each of the plots by adding seeds from 9 species that are currently abundant in the region of the study area and 2 southern species that have been predicted by models to increase in abundance in the region of our study. These seeds were planted in November and December of 2007 and began to germinate in mid-May. Since the time of their planting, the seeds and seedlings have been subjected to an array of challenges including: seed predation by small mammals, gypsy moth defoliation of newly emerged first leaves, foliar burning by above-average temperatures in early June, and stem browsing by small mammals. Despite these threats, we have sufficient numbers and diversity of seedlings in the plots to thoroughly meet the study's objectives. Half of each plot has "natural" germination and sprouting of woody and non-woody species (verses the other half of each plot with the controlled species composition). In May we began monitoring seedling germination and sprout budburst in the plots once a week. Height and stem diameter above root collar of all woody species in each plot is measured every 4 weeks. Leaf-level photosynthesis is measured once every 4 weeks and relative growth rate is measured twice during the growing season. At the end of the growing season half the seedlings will be harvested for above and below-ground biomass measurements and foliar chemistry analysis. Bulk soil properties were measured before the experimental treatments were initiated and nutrient availability and soil gas exchange are being measured.

Preliminary results and remaining work

Seedlings growth and root and basal sprouts have experienced warming and irrigation treatments for four months and will continue to do so for another 32 months or more. Therefore, preliminary results from the project are limited and should be considered truly preliminary. The date of seed germination was earlier in the heated plots compared to the irrigated and control plots, indicating a rapid response by species to the warming treatment (Fig. 3). This pattern is strongest among the 5 oak species included in the study, suggesting that oaks may benefit by advancing the beginning of growth in the spring more than other species.

The main seedling response variables to our heating and irrigation treatments are germination rate and seedling biomass accumulated. These reflect the integrated (and net) effects of soil pools and processes, and plant physiology, leaf morphology, and phenological controls. We have started measuring these factors and will continue to do so through the 3 years of the project to determine how they contributes to the observed variation in plant growth. Each year half of the germinated tree seedlings will be harvested to look at above-ground and below-ground biomass allocation. Finally, the un-altered, "natural" area of each treatment plot will continue to be monitored for responses of species composition, biodiversity, and biomass production to the warming and irrigating treatments.

Table 1. Weekly recorded precipitation at research site and weekly irrigation treatment amount. Irrigated plots received additional water once a week and the effective treatment was 25% above recorded precipitation. Irrigation amount was calculated by averaging long-term monthly precipitation records (1880-2000) and adding the equivalent of a 20% increase above the mean.

Week	Recorded precip (mm)	Irrigation (mm)
5/5/2008	34.6	4.4
5/12/2008	16.8	4.4
5/19/2008	43	4.4
5/26/2008	15.4	4.4
6/2/2008	2	4.9
6/9/2008	20	4.9
6/16/2008	31.2	4.9
6/23/2008	15	4.9
6/30/2008	8.2	4.9
7/7/2008	13.4	4.6
7/14/2008	14.2	4.6
7/21/2008	10.2	4.6
TOTAL	**224**	**56**
Irrigation treatment above precipitation in non-heated plots		**24.8%**

Figure 1. Two Kalglo infrared heating lamps suspended over one of eight 2X4m plot being experimentally warmed at our research site in central PA. This picture was taken a few days after heating was initiated in late winter, 2008.

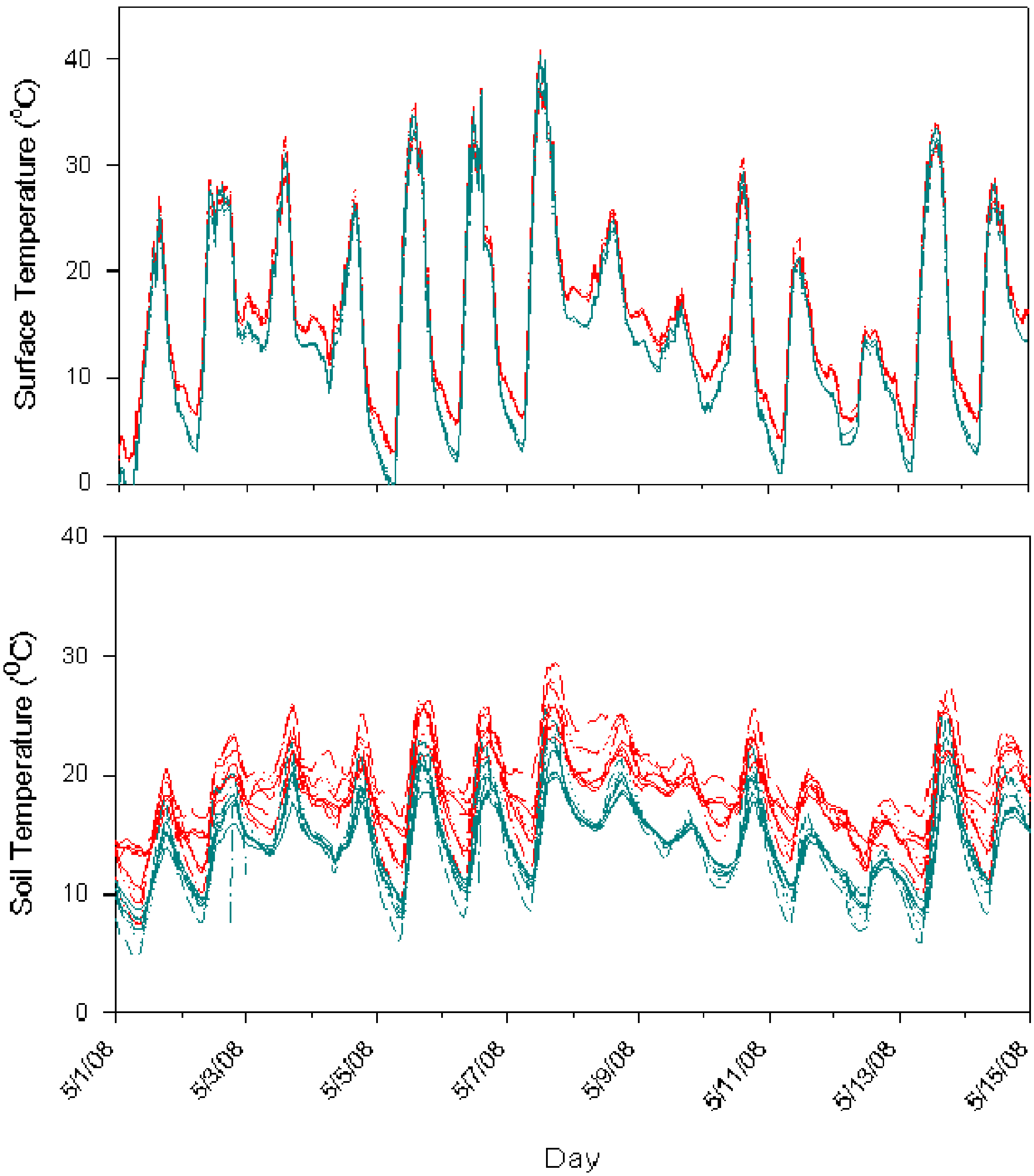

Figure 2. Surface and soil temperatures are being monitored in the 16 research plots; eight of which are being experimentally heated (red lines) and eight of which are unheated reference plots (blue lines). Heated plots have consistently higher temperatures that reference plots.

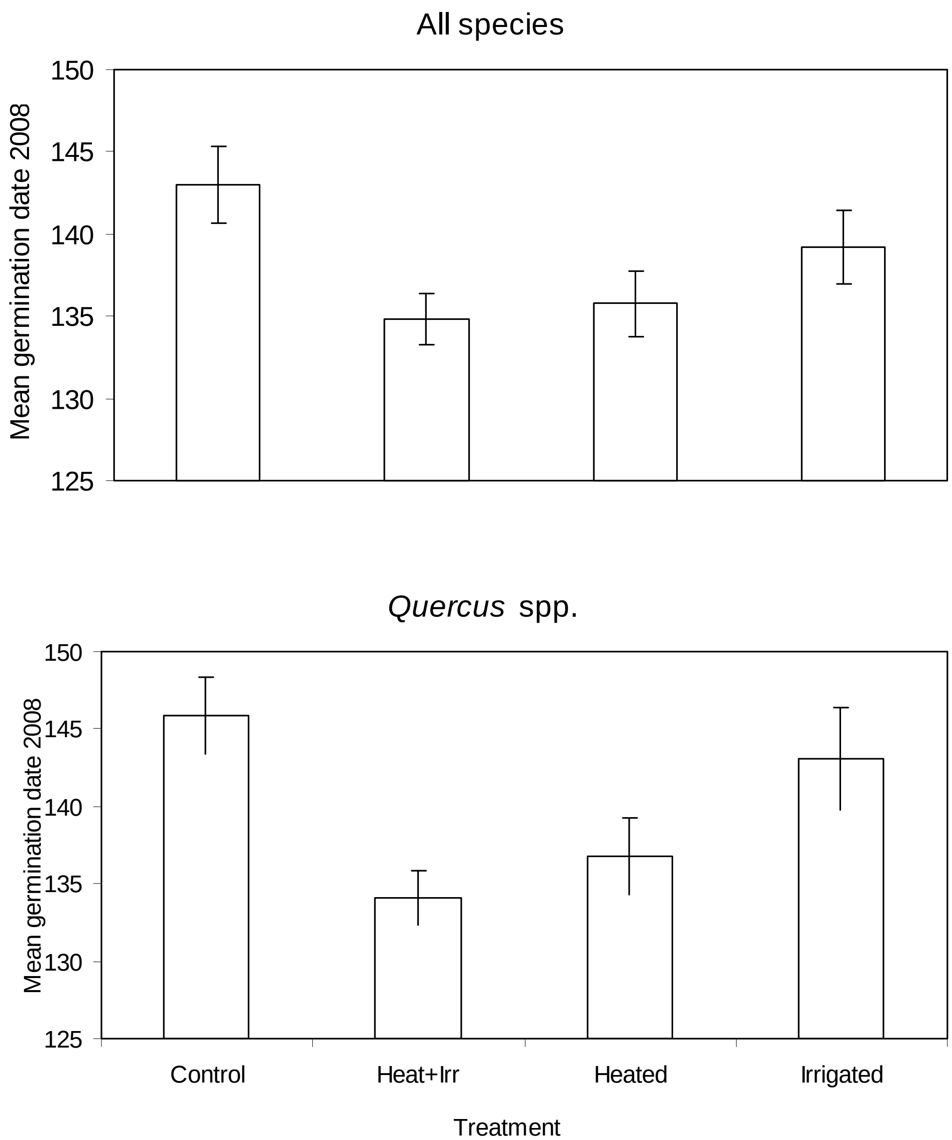

Figure 3. Mean germination date (+/- 1 SE) of planted tree seeds in four treatments: control, heated, irrigated, and heated+irrigated. Germination dates are average for 10 species found within the plots (top graph) and for only the 5 *Quercus* spp. (bottom graph).