Spruce and Peatland Responses Under Climatic and Environmental change

AN OVERVIEW OF THE SPRUCE PROJECT, A LARGE-SCALE STUDY OF INCREASED TEMPERATURE AND CARBON DIOXIDE EFFECTS ON A NORTHERN PEATLAND

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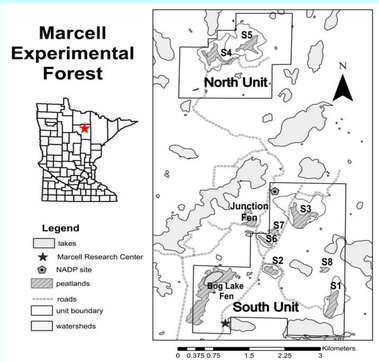
INTRODUCTION

Scientists at the Oak Ridge National Laboratory and the USDA Forest Service are developing a large-scale ecosystem study in which temperature and carbon dioxide (CO_2) will be experimentally increased to quantify effects of climatic forcing on a northern peatland – an ecosystem that is considered to be especially vulnerable to climate change and to have important feedbacks on the atmosphere and climate.

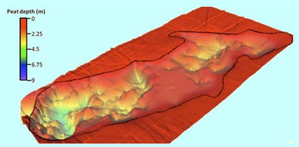
The experiment will allow for the evaluation of responses across multiple spatial scales. Design and prototyping is now occurring with full operation planned for 10 years starting in 2013. We plan to quantify thresholds for organism decline and regeneration, changing greenhouse gas emissions, and responses of biogeochemical and hydrological processes.

ENVIRONMENTAL SETTING

SPRUCE will occur on the 8.1 ha peatland in the S1 catchment on the Marcell Experimental Forest (MEF). The MEF is a research site of the Northern Research Station, USDA Forest Service. Long-term monitoring began in 1961 with forest management experiments starting during 1969. The landscape includes uplands, bogs, fens, lakes, and streams within the Marcell hills moraine complex that drains to both the Mississippi River and Hudson Bay.

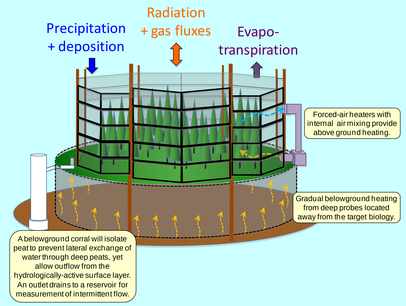


- The *Picea mariana* (black spruce) – *Sphagnum spp*. bog is ombrotrophic and located at the southern margin of the boreal zone.
- Peatlands at the MEF like S1 contain deep peat deposits that are perched several meters above the regional groundwater table.
- Responses of vegetation, large carbon pools in peat, and the water cycle are expected to have important feedbacks on the atmosphere and climate through changes in net emissions of CO_2 and CH_4



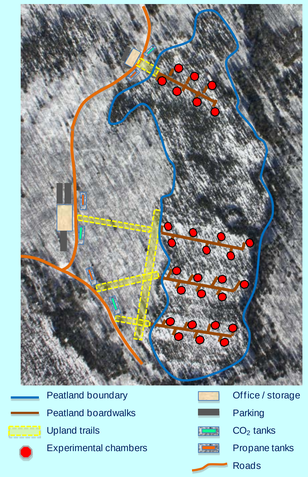
EXPERIMENTAL DESIGN

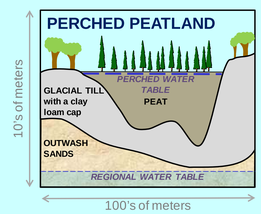
The final design (with 28 potential experimental units within a blocked design) will balance statistical demands and operating costs. A blocked ANOVA design with replication of warming and CO_2 treatments was originally proposed. We are also considering the application of a regression continuum of temperature treatments to be duplicated at elevated CO_2.

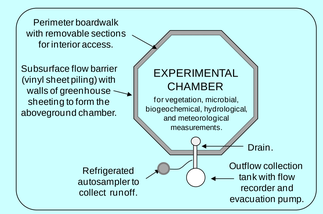


Chambers will:

- Be open topped with 12-m diameter internal study areas, 8-m tall sidewalls, and peat that is 2 to 4-m deep.
- Be warmed at levels from ambient to +9°C (above and below ground).
- Have elevated CO_2 in the range of 800 to 900 ppm.



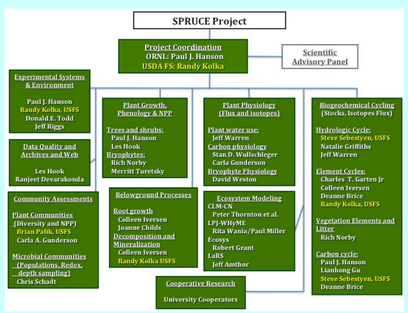




RESEARCH QUESTIONS AND OBJECTIVES

- How vulnerable are peatland ecosystems and their component organisms to atmospheric and climatic change?
- To what degree will changes in plant physiology under elevated CO_2 impact a species' sensitivity to climate or competitive capacity within the community?
- Will full belowground warming release unexpected amounts of greenhouse gases and solutes from high-C-content northern forests?
- What are the critical air and soil temperature response functions for ecosystem processes and their constituent organisms?
- Will ecosystem services (e.g., biogeochemical, hydrological, or societal) be compromised or enhanced by atmospheric and climatic change?

The SPRUCE experiment is being developed to determine ecological responses across a broad range of above- and belowground temperature increases, and how those responses to increased temperature will be altered by elevated atmospheric CO_2 concentration. The study will focus primarily on warming with elevated CO_2 acting as an important interacting factor that may negate enhanced decomposition (CO_2 or CH_4 release) from increased photosynthetic allocation of carbon belowground.



OPPORTUNITIES FOR COLLABORATION

- Canopy albedo changes.
- Remote sensing of canopy function.
- Microscale LiDAR.
- Bole respiration.
- Biogeochemical cycling of trace elements (e.g. Hg).
- Trace gas emissions other than CH_4.
- Mycorrhizal studies.
- N fixation.
- Herbivory.
- Arthropod populations.
- Amphibian and reptile populations.
- Food web linkages.
- Lichen productivity and decomposition.
- Pests and pathogens (host defenses vs. pathogen virulence).

PROPOSED MEASUREMENTS AND MODELING

- Plant community composition, growth responses, physiology, and phenology: tree demography and understory communities (ericaceous shrubs, tree seedlings, forbs, *Sphagnum spp*.); vascular plant production, bryophyte production, leaf and litter production, belowground production; photosynthesis and respiration; water relations.
- Soil microbial community composition.
- Meteorological and hydrological parameters needed to calculated water and energy budgets: water table elevations, surface water drainage from chambers, eddy covariance measurement of water vapor fluxes.
- Biogeochemical cycling responses with emphases on nitrogen, carbon, phosphorus, metals, and dissolved organic matter.
- Water and organic soil chemistry including nutrients, ions, metals, and organic matter (concentrations and compositional measures).
- Peat physical properties and geophysical imaging of the surface and subsurface environments.
- Mechanistic modeling leading to more comprehensive parameterization of peatland processes in general circulation models such as CLM.
- Water and trace gas fluxes with an emphasis on CO_2 and CH_4.

ADVANCING GLOBAL CHANGE SCIENCE AND ECOSYSTEM RESEARCH

- SPRUCE will provide quantitative evidence of the effects of climatic forcing by temperature and elevated CO_2 on northern peatland ecosystems and the vast C stores that are associated with the hydrology and biogeochemistry of these globally widespread landscape features.
- The data are crucial to predicting feedbacks on global climate as well as ecosystem productivity, water availability, and biogeochemical transformations in these ecosystems.
- The data will also provide valuable insight on climatic factors that affect carbon stocks and solute yields.

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