The PEATcosm Experiment

Climate, Fire, and Carbon Cycle Sciences

A research work unit of the USDA Forest Service Northern Research Station

Peatland ecosystems represent 3-5% of the land surface, but store 12-30% of soil organic carbon. However, this very large pool of carbon is vulnerable to loss to the atmosphere as CO_2 because of climate change. Lowered water tables caused by climate change or anthropogenic drainage can shift peatlands from being net carbon sinks to net carbon sources. In the north central US there are extensive peatlands that comprise the southern edge of a broad band of peatlands extending into northern Canada and Alaska. Current trends and climate models predict a general pattern of decreased water availability in the summers as a likely outcome of climate change. Precipitation patterns are also becoming more variable, with more occurrences of extreme rain events and summer drought in recent decades. In turn, these changes in climate can lead to increased water table variation, including large mid-summer declines in water table height. Plant communities in peatland can change in response to climate change. These community changes could then feed back to accelerate or decrease the amount of carbon lost from peatlands. We need more information to understand exactly how vegetation changes, in interaction with changing water tables, will influence the storage of carbon in peatlands.

In order to understand these interactions of climate change and plant communities in nutrient poor peatlands we have initiated the PEATcosm Experiment. Our goal is to gain fine control over both plant functional group presence and water tables using peat mesocosms that are otherwise as similar as possible. To do this, using funding from the U.S. Forest Service Northern Research Station Climate Change Program, we are using the U.S. Forest Service Houghton Mesocosm Facility (Figure 1) adjacent to the School of Forest Resources and Environmental Science at Michigan Technological University. We will establish a 3 plant functional group x 2 water table factorial experiment, with 4 replicates, in a completely random design. We will establish three bog communities (unmanipulated, minus sedges, and minus Ericaceae) and two water table treatments (low intraseasonal variability, higher mean water table; high intra-seasonal variability, lower mean water table) (Figure 2).

Figure 1: Surface view of the 24 1m^3 mesocosm bins (intact peat) located at the US Forest Service Forestry Sciences Laboratory.

We have entered the first phase of the PEATcosm experiment already, harvesting peat monoliths from a site in Minnesota in May 2010 and transferring them intact into our meter-cubed mesocosm chambers. During summer and fall of 2010 we built and tested our respiration and methane monitoring system, characterized plant

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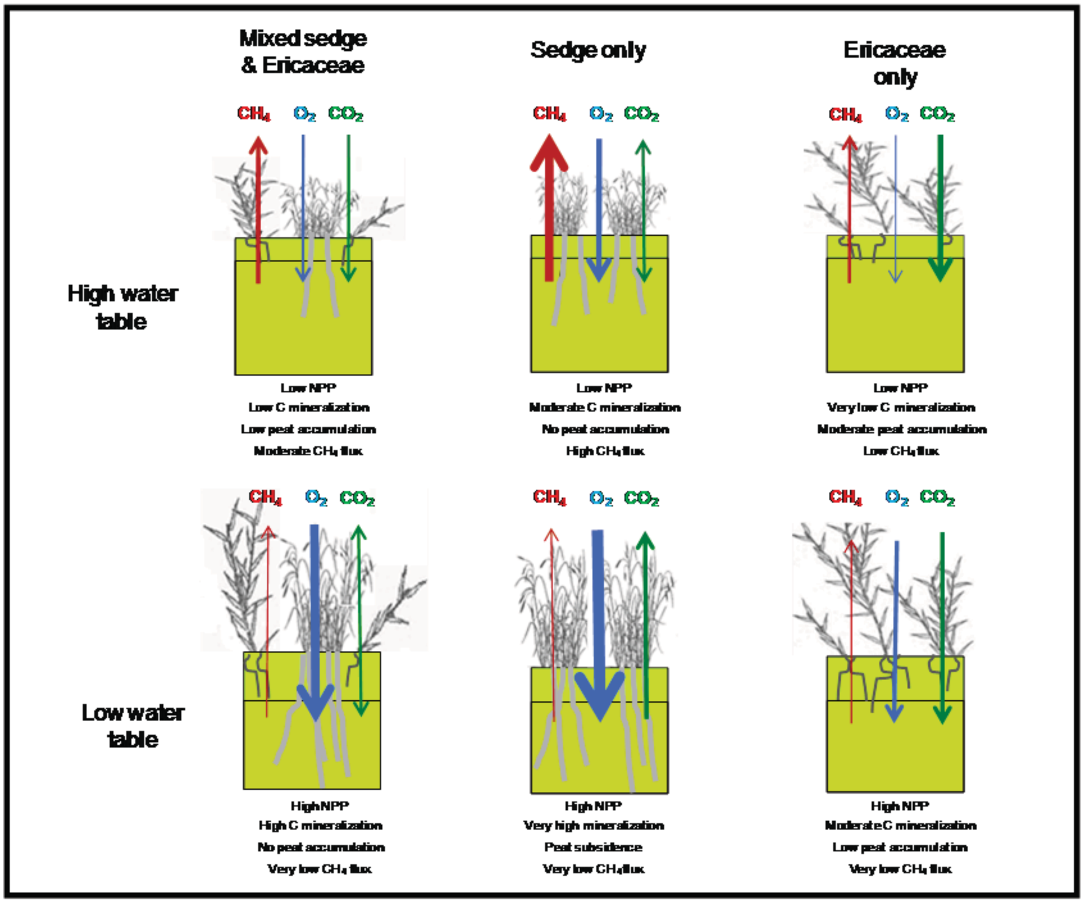

Figure 2. Conceptual model of plant community and water table interactions in oligotrophic peatlands. Sedges and Ericaceae have opposite effects on C mineralization and peatland C balance, which are expected to be especially pronounced as water tables decline. Sedges possess deep roots and aerenchyma (air-filled channels in roots). These provide oxygen to free-living saprotrophs in deeper peat, increase enzyme activity, and drive high C mineralization. In contrast, Ericaceae possess shallow roots, lack aerenchyma, and support ericoid mycorrhizal fungi. Together these suppress abundance and activity of free-living saprotrophs, and limit peroxidase activity, leading to low C mineralization. As water tables decline these root-mediated effects are accentuated because root productivity and depth of penetration increases.

communities, put in place a water supply system and a meteorological station, continued development of our environmental monitoring and water level control systems, and ran small-scale preliminary mini-mesocosm vegetation manipulations.

During spring 2011 we will finalize equipment installation and initiate the experiment. Thus growing season 2011 will be considered a re-equilibration year in response to the vegetation removal and initiation of the water table treatments. In early spring we will install minirhizotron tubes, sensors, and water level control systems, and monitor CO_2 and CH_4 flux in the mesocosms. In late spring we will

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randomly assign treatments to mesocosms, and initiate vegetation manipulations. These will be carried out by removing all active growth of either sedges or Ericaceae from eight mesocosms each, repeated at weekly intervals throughout the summer until the target functional group is eliminated. Manipulations will be accomplished by clipping stems as deep in the peat as possible while minimizing peat disturbance. After communities have been altered, water table manipulations will be initiated.

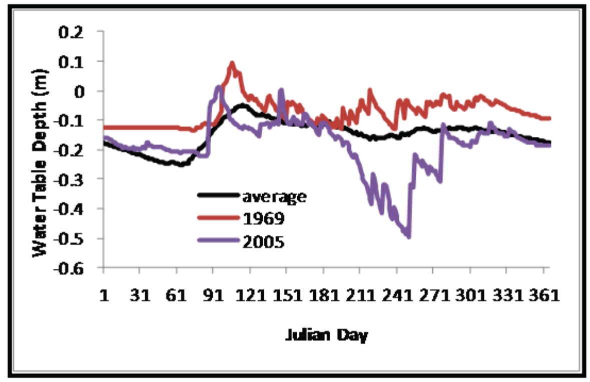

Figure 3: Long-term water table trends at Marcell Experimental Forest will be used to determine high and low water table manipulation treatments.

The water table manipulations will be based on long-term data from Marcell Experimental Forest, with the two target water table seasonal profiles (Figure 3) based on typical low variability, high minimum water table years (high water table treatment, e.g., 2005 in Fig. 3) derived from the almost 50 year record of precipitation and water tables. This variation is driven both by intra-annual variability in timing and interannual variability in amount of inputs. Thus, we will use the average precipitation profiles of the high water and low water years to manipulate water tables. Inputs will be regulated by a combination of artificial rainwater additions and rain-out shelters, as needed; outputs will be initiated by sufficiently high water tables sensed via pressure transducers, and controlled via outflow lines regulated by a proportional controller, with outflow captured for mass and chemical analysis.

Peat source and community

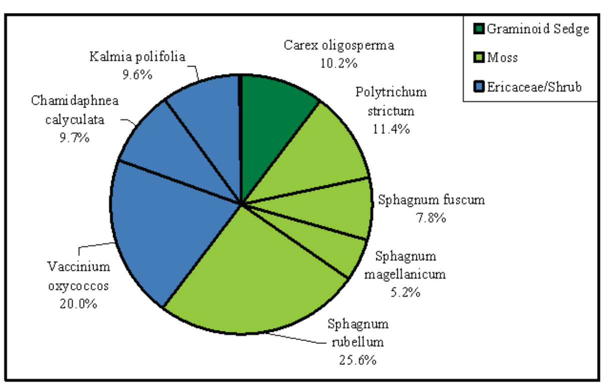

Figure 4: Mean relative frequency (percent) by species across all 24 mesocosm bins.

Intact peat cubes (1 m^3) were harvested from an extensive continental peatland (pH 4.0) in Meadowlands, MN with a custom cube box cutter and an excavator. Peat cubes were dropped intact into mesocosms with no compaction. Complete vegetation inventories (point intercept method) conducted on each bin (summarized in Figure 4) confirmed a relatively uniform presence of typical bog species, including ericaceous shrubs, *Sphagnum* and *Polytrichum* species and sedges, (solely *Carex oligosperma*).

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Mesocosm Facility
The Houghton Mesocosm Facility was built to promote ecosystem research to address critical environmental problems. It is a climate controlled tunnel into which are inserted 24 approximately 1 m^3 cube-shaped mesocosms. These mesocosms are constructed of stainless steel on three sides and the bottom, a glass face on the fourth side for visual access, and open tops exposed to ambient conditions. The interior of the stainless steel is coated with Teflon (PFA) to avoid exchange of metals with the interior environment. Exposed surfaces are insulated to minimize thermal conductance.

Side ports permit instrumentation insertion. The belowground environment is a fully accessible tunnel equipped with air conditioning, de-ionized water, and a National Instruments monitoring and control system linked to Labview software. Each mesocosm has been designed with two 80 cm long temperature probes with 5 thermistors each to monitor vertical and horizontal temperature gradients, a dissolved oxygen sensor, a pressure transducer to continuously measure water table depth, with the latter linked to a proportional control valve attached to a porewater intake manifold to regulate and collect outflow water when water tables are sufficiently high to initiate flow.

Expected Outcomes
We expect to increase our understanding of the interactions of climate change and peatland plant communities. This information will help us to predict how carbon stored in peatlands will respond to climate change, improving our ability to protect and manage peatlands, and to respond to climate change with effective adaptation and mitigation strategies.