Climate Change Response Program
Project Brief

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Climate Change Response Program

Past Forest Response to Climate Change Driven by Soils and Local Climate

Background

Climate change impacts to North American forests are already evident in the form of larger and more frequent droughts and wildfires. These stressors act alongside – and sometimes amplify – impacts from nonnative pests and disease, pollution, and habitat fragmentation. Stewarding natural resources in an ever-changing climate will require a long-term, strategic view that adapts management goals and approaches to the effects of both shifting climate baselines and increased variability. Better understanding of how local factors at the management-unit level influence climate change impacts can inform stewardship decisions. Paleoecological studies based on pollen and charcoal records from lake-sediment cores can be used to reconstruct past responses to climate variability, and suggest where and how to focus monitoring, management, and research. In this recently published research (*Tweiten et al. 2015*), we characterized soils, modern climate, and differences in past fire regime around 12 lakes in northwestern Wisconsin (see Figure 1) to determine whether observed landscape patterns in geophysical factors or local climate correspond to differences in past variability in forest composition (see Methods below).

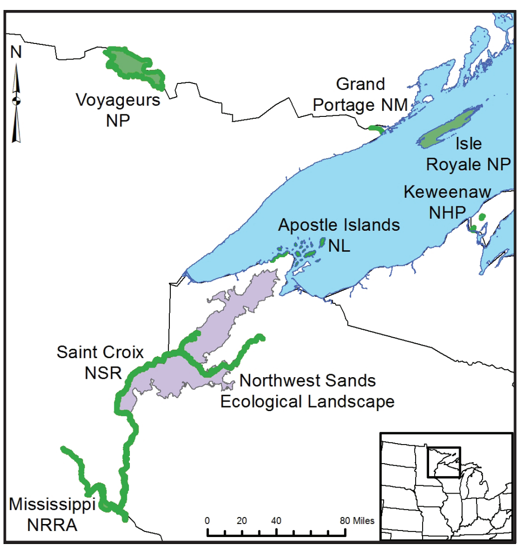

Figure 1. The study area – Wisconsin's Northwest Sands Ecological Landscape (purple) – in relation to nearby US national parks, including the Saint Croix National Scenic River, Mississippi National River and Recreation Area, Apostle Islands National Lakeshore, Keweenaw National Historical Park, Isle Royale National Park, Grand Portage National Monument, and Voyageurs National Park.

Results

Local factors – specifically soils and local climate – strongly influenced forest response to past climate change, and these influences were clearly evident despite the fact that study sites all occur within a small area (660 mi^2) on a relatively homogeneous glacial outwash landscape. Sites with finer-textured soils and higher water-holding capacity experienced greater long-term (century-to-century) forest community change, whereas forests on sites with poorer soils (coarser texture and lower water- and nutrient-holding capacity) changed much less overall and were more consistently dominated by a single forest type (see Figures 2 & 3). Soils and local climate also strongly influenced forest response to the warm/dry-to-cool/moist climatic transition 750 years ago from the Medieval Climate Anomaly to the Little Ice Age. A landscape-wide increase in white pine during the Little Ice Age was most pronounced on sites with soils of greater water-holding capacity and on sites further from Lake Superior with a warmer, drier local climate, suggesting that a moisture-related establishment threshold for white pine may have been crossed at these sites during the Little Ice Age. Similarly, fire frequency and intensity were influenced by local geophysical factors. Fires became generally more frequent and less intense during the Little Ice Age. Fire frequency increased most on sites with lower water-holding capacity, where they were associated

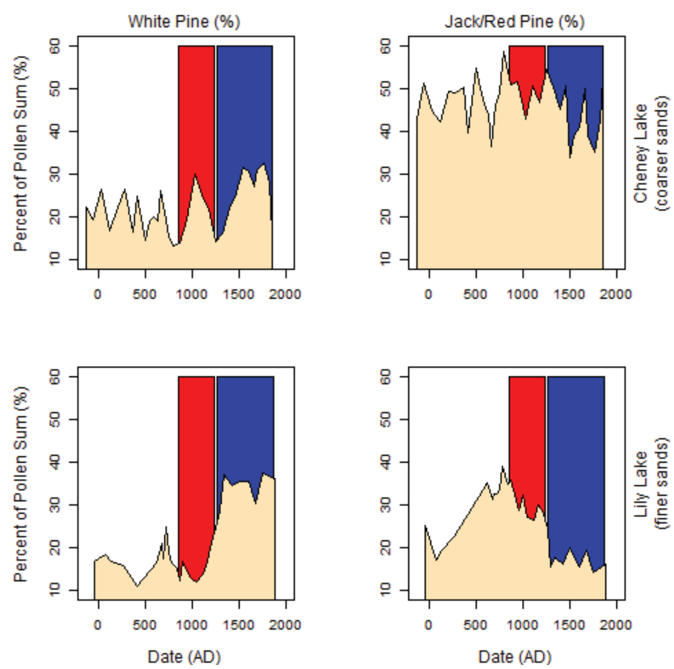

Figure 2. Change in the abundance of white pine (left) and jack/red pine (right), expressed as a percentage of the pollen sum, in two contexts – a sandy, well drained site (Cheney; top) and a site with finer-textured soil and higher soil moisture (Lily; bottom) – over the past two millennia. The red polygon in each graph indicates the relatively warm Medieval Climate Anomaly (~850-1250 AD) and the blue polygon indicates the subsequent relatively cool Little Ice Age (~1250-1875 AD).

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Results (cont'd)

with rapid pollen assemblage shifts over a few decades and high rates of short-term (decadal to century) forest composition change within the same overall jack pine-dominated forest type. A related study (Lynch et al. 2014 Canadian J. Forest Research 44:1331-1343) found less change in vegetation at sites with less protection from fire spread by surrounding lakes and wetlands (fire breaks), when compared with paired sites with similar soil textures but greater protection from fire.

Implications - Adapting to Change

This study of historical change shows that soil attributes and local climate shape forest response to climate changes and disturbance at very local scales, even within a sandy glacial outwash plain with limited soil variation. The prominence of these relationships on a relatively geologically homogenous landscape suggests that this understanding may be relevant to resource management on a broad range of landscapes.

Our results also show that system responses can be counterintuitive. In the case of the sand plain, for example, the most xeric, high-disturbance sites might be expected to change in response to a changing climate, but the paleo-record reveals much greater overall change on less xeric sites during the Little Ice Age.

Observed relationships between specific soil attributes and past changes in forest composition may not hold under the unique conditions of future climate, but these long-term observations show that soil differences are important influences on vegetation response to climate change. These findings support the call to consider the full range of biophysical features when planning for climate adaptation across regions, and suggest that managers tailor monitoring and management to the full range of soil and geophysical features at the landscape or management-unit level. A manager or management partnership, for example, could encourage stratification of forest research and monitoring across soil types to develop consistent baseline and trend data. This understanding is important because the effect of alternative management regimes and climate adaptation efforts on different soil types may be the most significant predictor of future forest composition.

Take Home Messages

- Forests on fine-textured sand with higher water-holding capacity saw the greatest long-term (century-scale) community change, but the least change at shorter time intervals.
- Forests on coarse, well drained sand varied much less overall and were consistently jack/red pine-dominated, but exhibited greater short-term variability.
- Forest response to the onset of the Little Ice Age was strongly influenced by soils and local climate; white pine increases were greatest on finer-sand/higher-moisture soils and in warmer/drier sites.

Methods

We investigated fire histories and forest change over the past ~2,000 years on a sandy glacial outwash plain in northwestern Wisconsin (Figure 1) using sediment cores from twelve lakes that encompass a 660-mi^2 (1700-km^2) area. The topography is flat to gently rolling, and streams are rare. This region's climate is humid continental and is influenced by Lake Superior, especially in the northeastern section.

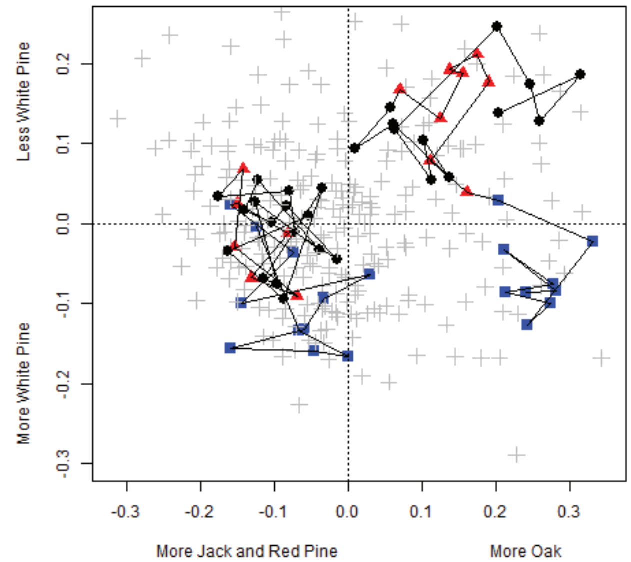

Figure 3. Forest compositional variability in two contexts (see Figure 2 caption) over the past two millennia, expressed in terms of placement of each sample in each record as a dot within a non-metric multidimensional scaling of all samples from all 12 records (see Methods in *Tweiten et al. 2015* for details). Cheney Lake is on the lower left of the diagram and Lily Lake is on the upper right. Samples plotted closer to each other in the diagram are more similar in pollen assemblage than samples plotted further away from each other. As the axis labels indicate, samples plotted to the left have more jack/red pine pollen, samples to the right have greater oak pollen percentages, and samples plotted towards the bottom have higher amounts of white pine pollen. Samples from a site that are adjacent in time are linked with a solid line, and samples are also color-coded by time period as follows: pre-Medieval Climate Anomaly – black diamonds, Medieval Climate Anomaly – red triangles, Little Ice Age – blue squares.

Methods (cont'd)

Both winter and summer temperatures show the cooling effect of Lake Superior, and proximity to Lake Superior also influences (increases) total snowfall and total precipitation. Soil attributes, by contrast, show a heterogeneous pattern – soils across the sand plain are generally nutrient-poor sands with low water-holding capacity, but the northeastern and southwestern sections have finer-textured loamy sands and sandy loams. Coarse, well-drained soils make the entire landscape susceptible to drought and recurring fires, and therefore favor more open forests dominated by pines and oaks that tolerate drought and reestablish quickly after fire. The sand plain is a mosaic of different land owners and management goals, including the NPS, US Forest Service, Wisconsin Department of Natural Resources, six counties, and private/industrial landowners. The landscape includes numerous Conservation Opportunity Areas under Wisconsin's Wildlife Action Plan, rare species such as the Kirtland's warbler, Karner blue butterfly, and sharp-tailed grouse, and areas managed with prescribed fire to promote open, shrubby barrens communities. We used the region's known history of climate variation to compare the rate and magnitude of vegetation changes among sites in different landscape contexts during a relatively warm period known as the Medieval Climate Anomaly (~850-1250 AD) and a subsequent cool phase known as the Little Ice Age (~1250-1875 AD).

More Information

This project is part of ongoing work of the National Park Service Climate Change Response Program and collaborators to support park adaptation to changing conditions. To view the full publication, **Tweiten, M.A., Calcote, R.R., Lynch, E.A., Hotchkiss, S.C., and Schuurman, G.W. 2015**. ***Geophysical features influence the climate change sensitivity of northern Wisconsin pine and oak forests*. Ecological Applications** 25:1984-1996, click *here.*