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Executive Summary

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Projecting Consequences of Altered Atmospheric Chemistry for Carbon Sequestration by Wisconsin's Aspen Forests

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Background

Wisconsin's forests harbor the potential to sequester considerable amounts of the carbon emitted (as carbon dioxide) through fossil fuel combustion, thereby helping to mitigate effects of anthropogenic emissions on atmospheric chemistry and global climate. In turn, Wisconsin's forests are sensitive to atmospheric levels of carbon dioxide (CO_2), ozone (O_3) and other trace gases, which have increased substantially in the past several decades. The majority of these increases are known to be anthropogenic in origin, and, based on plausible emission scenarios, these trends will likely continue into the foreseeable future. ***How will carbon sequestration in Wisconsin forests be affected by future changes in atmospheric chemistry?*** The answer to this key question is complicated by the fact that the various primary and secondary air pollutants have different effects on trees. In particular, elevated CO_2 generally stimulates tree growth, whereas elevated O_3 has the opposite effect.

Research Objective

The principal aim of this study was to predict relative impacts of present and anticipated future levels of tropospheric O_3 and CO_2 on potential rates of carbon sequestration by Wisconsin's trembling aspen forests. Trembling aspen was chosen as the target tree species because 1) it is, from economic and ecological standpoints, an important component of Wisconsin's forests, and 2) there is a sufficient body of information concerning its responses to changes in atmospheric chemistry. Currently, no other Wisconsin tree species meets these criteria. The tropospheric O_3 and CO_2 levels examined in this assessment were bracketed on the low end by ambient concentrations of both gases recorded during the past 5 years, and on the high end with levels that could be realized by the end of the 21st Century. These include a 30% increase in the growing-season average for tropospheric O_3 concentration, and nearly a doubling in CO_2 concentration.

Methods

We addressed our objective with a three-phase approach. The first involved calibration and validation of a canopy process model (BEWDY), which we then used to simulate aspen canopy photosynthesis under various scenarios of elevated CO_2 and/or O_3, at specific locations throughout Wisconsin. Simulation results were linked directly to C sequestration through the assumption that relative effects of atmospheric chemistry on C sequestration rate were proportional to corresponding effects on canopy photosynthesis. In the third phase, model output was used to determine spatial patterns of aspen response to altered atmospheric chemistry across the state. A brief description of each phase is provided below:

Model Calibration

- During the growing seasons of 1998, 2000 and 2002, we conducted an array of field measurements, at the Aspen FACE facility (near Rhinelander, WI), to assess the structural, biochemical and functional responses of aspen foliage to elevated concentrations of CO_2 and O_3.
- Using these data, we generated empirical Weibull functions characterizing the negative sigmoidal responses of leaf photosynthetic parameters to cumulative O_3 exposure.
- Using a canopy process model (BEWDY) that was calibrated with our empirical relationships, we estimated relative effects of elevated O_3 and CO_2, singly and in combination, on the amount of

carbon sequestered by aspen canopies throughout a growing season at the Aspen Face site.

- We then assessed the accuracy and precision of BEWDY by evaluating the relation between observed and estimated treatment effects on carbon sequestration rates of experimental aspen stands at the Aspen Face site.

Estimating relative effects of altered atmospheric chemistry on aspen across Wisconsin

- Hourly average values for O_3 concentration and micrometeorological parameters, recorded at various locations in and around Wisconsin during each growing season from 2001 through 2005, were acquired from the EPA data repository for atmospheric chemistry (AQS) and the FAA/NWS weather data networks (AWOS/ASOS).
- Based on these data, we simulated canopy photosynthesis (using BEWDY) for each of the five growing seasons, at 27 locations, under recent micrometeorological conditions and several scenarios of altered atmospheric chemistry: recent O_3 levels, and 10-30% increases in O_3 concentration in combination with elevated CO_2 (3 levels: recent, 560 ppm and 700 ppm). Using recent conditions in the (hypothetical) absence of O_3 as a reference, we calculated relative impacts of altered atmospheric chemistry under each of the 12 scenarios, for each of the five growing seasons (2001-2005).

Determining spatial patterns of aspen response across Wisconsin

- Based on spatially explicit, 5-year averages for each scenario, we generated statewide maps of aspen canopy response to various combinations of atmospheric change using ordinary kriging techniques.
- The resulting spatially explicit data were used to create county-level predictions of average aspen response, which were then scaled to a state average based on the estimated acreage of each county currently occupied by aspen-dominated forest.

Results and Inferences

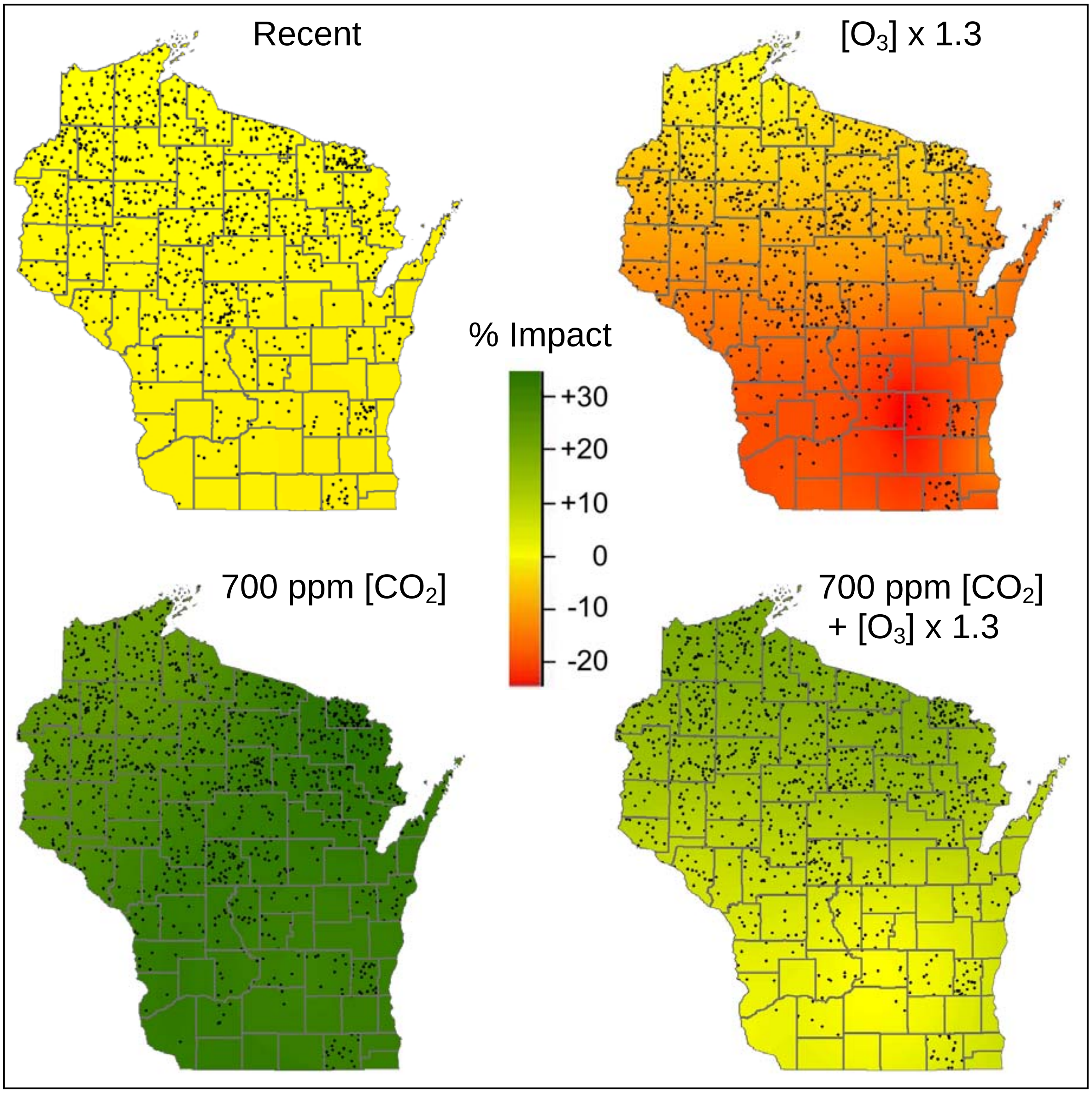
Given the spatially explicit nature of our findings, we have included in this summary maps showing relative impacts of various levels of tropospheric O_3 and CO_2 on aspen forests throughout the state (**page v**). Several inferences can be drawn from these maps:

- Across Wisconsin, the negative influence of O_3 on carbon sequestration by aspen has been modest in recent years. On average, sequestration rates appear to be roughly 2% less (range 1-3% across locations and years) than they would be in the absence of O_3.

- Plausible increases (e.g., 30%) in O_3 levels are predicted to cause substantial reductions in aspen carbon sequestration, especially in the southeastern quarter of Wisconsin, where decreases in certain years may approach or exceed 30%.

- If O_3 levels do not increase, the anticipated doubling of CO_2 concentration by 2100 will lead to an estimated 29% increase in the rate of aspen carbon sequestration. If, however, levels of O_3 increase by as little as 30%, the stimulus from elevated CO_2 will, statewide, be cut in half. In southeastern Wisconsin, the CO_2 stimulus would be completely offset by the damage caused from elevated O_3.

- Some of the geographic variation in impact is attributable to variation in growing season climate. This points to a key uncertainty regarding our predictions – potential influences of a changing climate on forest responses to altered atmospheric chemistry.



Predicted relative responses of trembling aspen forests, in terms of carbon sequestration rate, to recent and anticipated future levels of tropospheric ozone (O_3) and carbon dioxide (CO_2) in Wisconsin. Reference sequestration rates (equivalent to response = 0) are those estimated at a recent ambient CO_2 concentration (photoperiod average ~360 ppm during the growing season) in the absence of O_3. Scenarios include an increase in the growing-season average for photoperiod CO_2 concentration to 700 ppm, a 30% increase in the growing-season average for O_3 concentration (O_3 x 1.3), or both combined. Spatially explicit extremes in forest response (based on a five-year average) include a 34% stimulation of sequestration rate in elevated CO_2 (at recent O_3 levels), and a 23% decrease in elevated O_3 (at the recent CO_2 level). Density of stippling represents proportional acreage of aspen-dominated forests in each county.