ENVIRONMENTAL AND ECONOMIC RESEARCH AND DEVELOPMENT PROGRAM

Climatic Analogs, Climate Velocity, and Potential Shifts in Vegetation Stucture & Biomass for Wisconsin Under 21st-century Climate-change Scenarios

Executive Summary
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Executive Summary

Climate is a fundamental constraint on the distribution, diversity, and abundance of species, and projected climate changes over this century are expected to have a major effect on US species, ecosystems, and the services that they provide. Recent temperature rises appear to be already affecting the most climatically sensitive and fast-responding components of Wisconsin landscapes, with observed decreases in the length of lake ice cover, earlier timing of spring flowering, and the earlier spring arrival of migrating birds. In the US and in the Northern Hemisphere, many species ranges are shifting northwards and upwards, consistent with forcing by warmer temperatures. Species distribution models driven by climate scenarios for this century consistently predict that these range shifts will continue as temperatures rise.

In Wisconsin, average annual temperatures in Wisconsin increased by 0.6°C (1.1°F) between 1950 and 2006, while winter temperatures increased by 1.4°C (2.5°F) over the same period. Annual precipitation has increased by 10%, with much of that increase attributable to an increase in the frequency and intensity of heavy precipitation events. By the middle of this century, Wisconsin temperatures are projected to increase (on average, across the state) by 2.2 to 5°C (4 to 9°F), a rate about four times the rate observed between 1950 and 2006. The direction of annual and summer precipitation changes is less certain, but global climate models consistently predict increases in winter precipitation and the frequency of extreme precipitation events. Given the observed historic climate changes in Wisconsin and the likelihood of continued climate change driven by rising greenhouse gas emissions, there is a need to assess the potential effects of projected climate changes on Wisconsin's species and natural resources and use this information as the basis for adaptation strategies designed to improve the resistance, resilience, and response paths available to Wisconsin's ecosystems. A major milestone in this effort was the formation of the Wisconsin Initiative on Climate Change Impacts (WICCI) and its 2011 report: Wisconsin's Changing Climate: Impacts and Adaptation.

In this EERD-supported project, we build upon the 2011 WICCI report by applying its downscaled 21st-century climate projections for Wisconsin to three sets of analyses designed to assess and summarize the potential effects of climate change on Wisconsin's species and landscapes: 1) Climate-analog analyses, which identify contemporary analogs for the future climates projected for Wisconsin (Section 2), 2) Climate-velocity analyses, which measure the spatial rate of climate change (Section 3), and 3) dynamic global vegetation model simulations of Wisconsin vegetation and carbon sequestration (Section 4). In these analyses, we used climate change simulations for three standard socioeconomic scenarios: the B1 scenario, in which atmospheric CO_2 concentrations are stabilized at 550 parts per million (ppm) by the end of this century, the A1B scenario, which is a 'business-as-usual' scenario in which CO_2 reaches 720 ppm by 2100AD, and the A2 scenario, a high-end scenario in which CO_2 reaches 820 ppm by 2100 AD.

All analyses point to the potentially transformative effects of changing climates over this century upon Wisconsin vegetation and landscapes. For example, by the end of this century, under the A2 scenario, Madison's climates may resemble those in eastern Kansas, while Superior, WI's climates may resemble those found in Milwaukee. Under the A2 scenario, there is little or no overlap between Wisconsin's contemporary climates and those projected for the end of this century. Instead, the range of potential climatic analogs for late-century climates in Wisconsin stretches across a broad band stretching through Oklahoma, Kansas, Missouri, Iowa, Illinois, Michigan, Ohio, and West Virginia. Conversely, under the B1 CO_2-stabilization scenario, projected climates for northern Wisconsin most resemble those currently found in southern Wisconsin and Michigan, while the projected climates for southern Wisconsin most resemble current climates in Illinois, Iowa, and eastern Kansas.

The spatial velocity of climate change varies widely among climate variables: temperature-related variables such as mean annual temperature or mean winter temperature have the highest velocities, while precipitation related variables tend to have the lowest velocities. The highest velocities are associated with winter temperature, reaching 5.6 km yr^{-1} (averaged across scenarios). For comparison, species ranges shifted during the climate warming accompanying the last deglaciation at rates estimated to range from 0.1 to 1 km yr^{-1}, and recent latitudinal range shifts are on the order of 1.7 km yr^{-1}. Hence, the possibility exists that some dispersal-limited species will not be able to migrate quickly enough to stay within their climatic zones without assistance. Moreover, because species are differentially sensitive to particular aspects of the climate system, the strong differences among climate variables in their projected climate velocities offers a potentially powerful mechanism for community reshuffling and the emergence of novel mixtures of species. Species that are temperature-sensitive and able to migrate quickly may experience the largest rates of northwards expansion, while species that are less temperature-sensitive or are dispersal-limited may experience either stable or contracting ranges.

Vegetation simulations by the Lund-Potsdam-Jena (LPJ) model consistently indicate that northern evergreen trees will decline in their abundance and extent in Wisconsin, while the ranges and abundances of temperate deciduous species will expand northwards. The simulated loss of evergreen tree cover ranges from 37% to 62% by 2050 and from 91% to 100% by 2100. Evergreen losses are highest for the warmer climate simulations and when the effects of climate are not ameliorated by the physiological effects of rising CO_2 on plant productivity and water use efficiency. All LPJ simulations indicate a northward expansion of deciduous trees, but differ over whether there will be a loss of deciduous trees in southern Wisconsin. In all scenarios, the amount of carbon stored in Wisconsin's natural ecosystems is predicted to decrease during the 21st century. By 2050, the loss ranges from 318 gC m^{-2} (1.7%, B1) to 1975 gC m^{-2} (10.4%, A2fixCO2). By the late 21st century, the projected loss ranges from 1037 gC m^{-2} (5.4%, B1) to 5,083 gC m^{-2} (26.7%, A2fixCO2). In the LPJ simulations, the physiological effect of CO_2 mitigates (by about two-thirds) but does not neutralize carbon losses caused by climate change alone. The importance of the CO_2 physiological effect remains uncertain and a major area of scientific research; these simulations are probably nearer to the upper-end of the strength of this effect. Projected carbon losses are highest for the climate simulations that predict the most warming and drying in Wisconsin. For the high-end A2fixCO2 scenario, Wisconsin natural vegetation is projected to lose 18.9 Tg CO_2 per year. By 2100AD, this amount increases to 29.7 TgCO_2 per year. The amount of carbon lost in the B1 scenario is about 40% of the A2 projections, suggesting a positive feedback in which efforts to mitigate global CO_2 emissions further reduces the emissions from Wisconsin terrestrial ecosystems.

In summary, all climate scenarios and all analyses based upon these scenarios project at least some amount of climate-driven vegetation change in Wisconsin over the next several decades to century. However, the difference in projected climate impacts between the B1 and A2 scenarios are large. These analyses indicate a utility to developing both climate-adaptation and climate-mitigation strategies: laying the policy and infrastructure groundwork for adapting to the climate changes that are inevitable or at least highly probable (approximated by the B1 scenario) while developing mitigation strategies that reduce greenhouse gas emissions and hence avoid the higher-end scenarios with the fastest rates of projected climate change. There is a critical need to develop adaptation strategies that will increase the resilience of Wisconsin ecosystems to projected climate change and, when necessary, ease the transition to the new communities and mixtures of species that may arise in this state over the coming century. The prospect of novel ecosystems, shaped by the intersection of climate change with new patterns of land use, new species introductions, and other drivers of ecological change, poses a new but solvable challenge to decision makers, resource managers, and other stewards of Wisconsin's natural resources. Priority actions include the testing and development of climate-adaptation management strategies, improved monitoring capacity in order to obtain early warning of gradual or abrupt change, and investment in ecological forecasting capacity.

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