Reducing Uncertainty:

Sugar Maple Forecasting Results Summary

MAD LAB

Mount Allison
Dendrochronology Lab

Ben E. Phillips and Colin P. Laroque
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Mount Allison Dendrochronology Laboratory,
Department of Geography and Environment,
Mount Allison University
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Introduction

Sugar maple is a tree species that has been identified by research in areas throughout its range, to have been affected by what is known as dieback. Dieback is caused by climatic injury internal to the tree resulting in the death of branches in the upper crown. Connections to winter temperatures and droughts have been made to dieback events. In 2008 a study by the MAD Lab identified sugar maple as a species potentially susceptible to climate change events. The Fundy Model Forest funded this study to find out if there was cause for concern regarding future climate, dieback, and sugar maple viability.

By comparing sugar maple growth over the past century with recorded climate data we can learn what components of the climate help or hinder the tree species. Then by using future climate forecasts we can project how the trees may respond to future climate scenarios. The following text summarizes the research results, for more detail and references please see the full report.

Future Climate

The Special Report on Emission Scenarios (SRES) produced by the Intergovernmental Panel on Climate Change (IPCC) outlines several different potential future emission scenarios upon which global climate models base their forecasts of climate change. Using these scenarios global climate models predict between 1.1 - 6.4°C increases in global temperatures by the year 2100. Under the A1b scenario, which predicts a median temperature gain of 2.8°C by the end of the century, many climate changes in the Maritimes can be expected.

The most dramatic of those climatic changes projected to occur by the year 2100 under the A1b scenario includes a 70% reduction in annual snow depth for southern areas of the Maritimes but little change in more northern areas. Winter temperatures driving these snow pack changes are expected to increase by an average of 6°C across the Maritimes. The same warmer temperatures causing lower snow depths in the south will contribute to a warmer and longer growing season. The number of growing degree days is forecast to increase by 44% in northern areas and 52% in southern areas. Summer temperature maximums will also increase by approximately 2°C in northern areas and by 4°C in southern areas. Precipitation will continue to vary from year to year but similar volumes should continue. Perhaps the most notable change in precipitation will occur in southern areas of the Maritimes where an 11% reduction in summer rainfall amounts is predicted.

The climatic changes noted here are based on the third version of the Canadian Centre for Climate Modeling and Analysis (CCCma) Coupled Global Climate Model (CGCM3). The A1b scenario used here represents a leveling off of CO_2 emissions at 720 parts per million (ppm) by the year 2100. This number is vastly higher than current levels which are nearing 390 ppm. The range of SRES climate change scenarios show atmospheric CO_2 concentrations at the end of the century between 550 and 1000 ppm. Based on these estimates an outcome resembling the A1b scenario would be a moderate amount of climate change. Although we have used only one scenario here to describe future climate it is impossible to tell what level of future CO_2 emissions and thus climate warming, will be realized due to a combination of unpredictable global human influences and natural system response.

Sugar Maple Annual Growth Rates

Our research on sugar maple trees in the Maritimes is based on tree-ring samples collected from ten sites covering most of New Brunswick and central areas of Nova Scotia. Measurements of these samples allowed us to construct an annual record of the trees' response to their local environments. This was done at each of the ten sample sites and Figure 1 shows an average of all of the sampled sites.

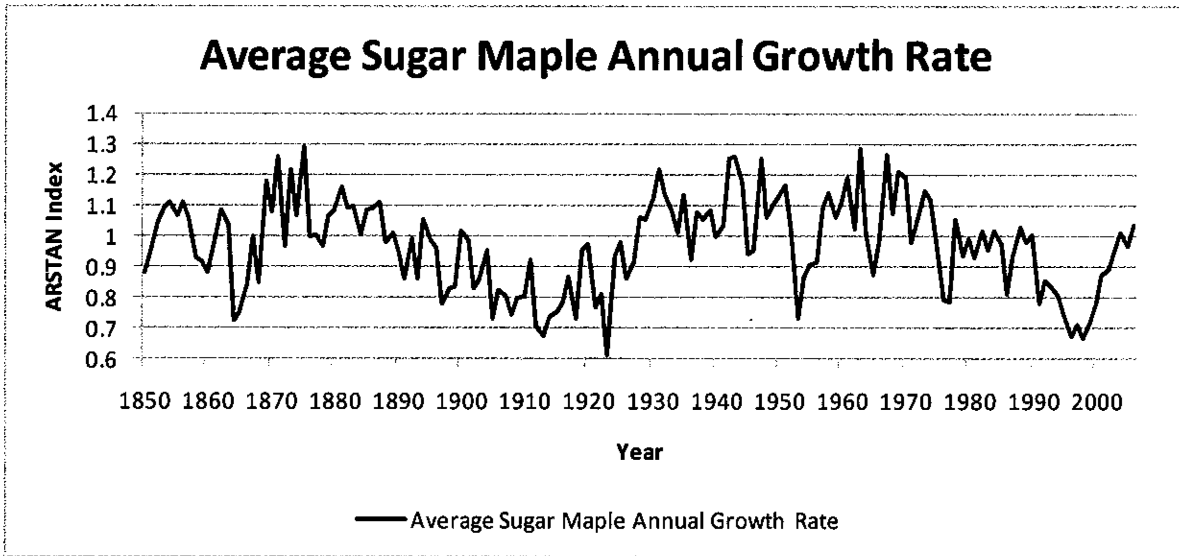

Figure 1. Sugar maple radial growth curve representing sample sites from N.B. and N.S.

Over the past two centuries sugar maple trees have experienced fluctuating radial growth rates and experienced frequent growth suppression periods. These radial growth suppression periods have suspected connections to winter thaw/refreeze events and we have strengthened those links in this study. Although it has been difficult to define exactly what temperature situations can cause injury to sugar maple trees we do see sudden radial growth depressions following late winter and early spring thaw/refreeze events. By comparing past sugar maple radial growth rates to past climate data we can understand what aspects of climate are the greatest influence on growth. Beyond thaw/refreeze events sugar maples are sensitive to too much snow or too little snow during the winter months; they do not respond well to warm Aprils or rainy Mays, cool or wet Junes are preferable to warm or dry Junes, and a combination of various summer temperatures and precipitation amounts drive their radial growth rates. The particular months of the year which influence the growth of sugar maple share some similarities across the landscape as discussed above, however, they also vary depending on the characteristics and geographical positioning of the site where they are situated.

Further to these monthly influences on sugar maple radial growth, we have also found that large scale ocean-atmosphere oscillations that fluctuate over long time frames have a substantial effect on sugar maple. Over the past 150 years sugar maple radial growth rates have followed long-term trends in the Atlantic Multidecadal Oscillation (AMO) and the North Atlantic Oscillation (NAO). The AMO is a measure of sea surface temperature anomalies in the North Atlantic Ocean and the NAO measures sea level pressure anomaly. The NAO has a large influence on the track of weather events across the eastern seaboard of North America, over the Atlantic, and into Europe while the AMO has been linked to higher temperatures and drought conditions in central North America. These ocean-atmosphere interactions vary from month to month and year to year, yet they also have longer term positive or negative phases which undulate over multiple decades. This long term undulation is evident in Figure 1 where the influences of the AMO and NAO are noticeable in the radial tree growth curve.

Sugar Maple Future Climate Stress Potential (2010-2024)

Here we present maps of future climate stress potential. Definition of time period, geographic boundaries, and climate stress expectation were substantiated through four categories of evidence. These include: radial growth to climate response, the future climate trends extracted from the CGCM3, the ecological land classification and most importantly, the probability trends of the AMO and NAO. Exact boundaries were subjectively chosen using the four categories of evidence.

The period ranging from 2010 to 2024 is assigned relatively low expectations for climate stress potentials (Fig. 2). The most important factor exerting influence over this period should be the AMO. It is generally thought the current positive phase of the AMO will persist into the immediate future. The positive phase of the AMO is historically associated with greater sugar maple radial growth, therefore the longer the current positive phase persists, the longer sugar maples should thrive. The next principal climatic force on radial growth success of sugar maple is the NAO. When the NAO is in a positive multidecadal phase, sugar maple tends to respond with poor radial growth. Although predictability of the NAO is very poor, based on long-term trends we suggest that the current downward trending phase of the NAO should soon flip to a negative phase, which has historically been associated with increased sugar maple radial growth. Recent NAO phases have experienced longer phase lengths which could result in an extended negative phase. This assumption is only based on NAO trends but if the coming negative phase persists half as long as the current positive phase has, it should easily extend beyond 2025.

Neither of the forecast summaries from the CGCM3 nor the sugar maple radial growth models indicates any substantial changes in climate or growth rates over the next 15 years. Finally, the background climate fluctuation must not be forgotten and it should be assumed that a certain low level amount of climate induced stress will occur in the absence of other major climatic events. If all of these assumptions hold true the northern regions should be able to avoid much of the normal climate stress due to the protective snow cover there and higher precipitation rates, while southern areas should only experience low to medium levels of climatic stress.

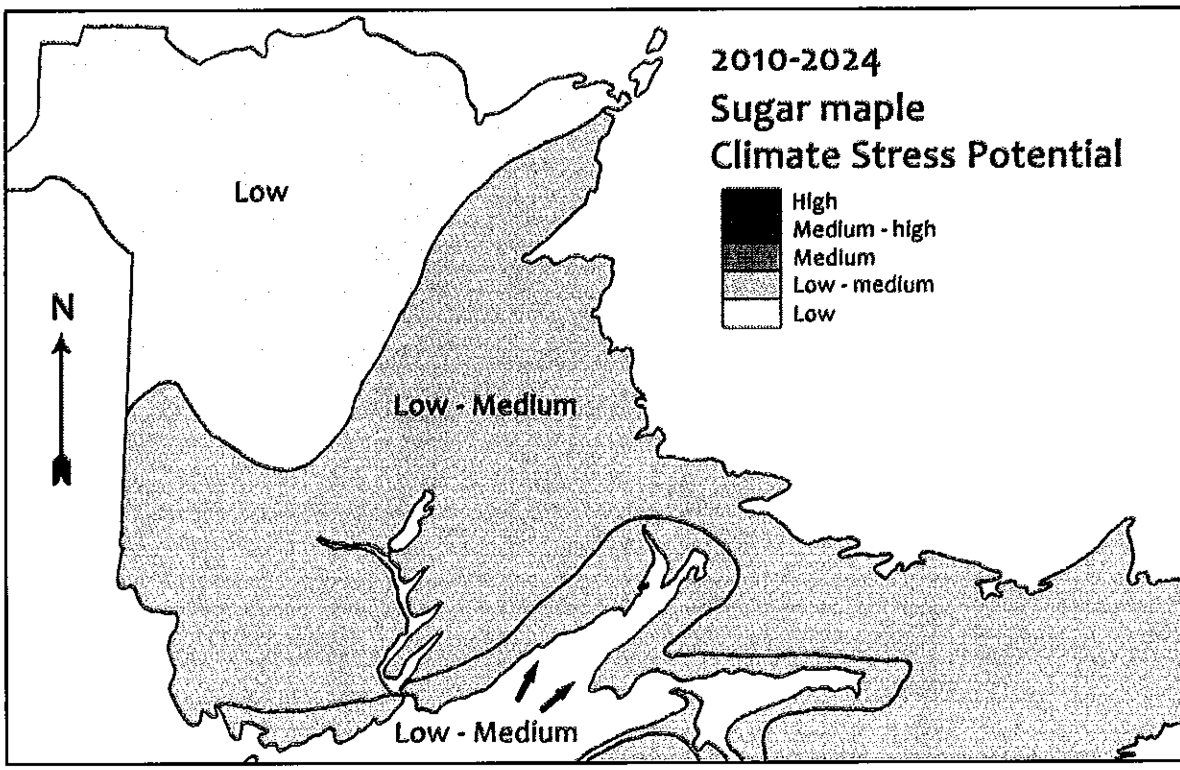

Figure 2. Climate stress potential map for sugar maple from 2010 – 2024.

Sugar Maple Future Climate Stress Potential (2025-2050)

The period ranging from 2025 to 2050 is assigned relatively high expectations for climate stress potentials (Fig. 3). The most important factor exerting influence over this period should be the AMO. The chances of the AMO switching to a negative phase by 2030 are over 90%. The negative phase of the AMO is historically associated with reduced sugar maple radial growth therefore the transition to a negative phase should result, not only in lower radial growth rates, but a diminishment in the ability of sugar maple to recover from injury. If recent trends of the NAO continue as they have over the past 60 years, another extreme positive phase should be entered sometime during the 2025-2050 period. This assumption is highly speculative and the phase change could come much sooner or later than the 2025 date. During the 1980s and 1990s a negative phase of the AMO and a positive phase of the NAO coincided with radial growth suppression of sugar maple across all sites sampled in this study. The Bay of Fundy area has shown some resistance to AMO influence in the past and has been given a lower potential of climate stress for this reason. Although uncertain, a synchronous period of negative phase AMO and positive phase NAO is most likely to repeat in the 2025-2050 time period.

Both the forecast summaries from the CGCM3 and sugar maple radial growth models indicates substantial changes in climate and growth rates by the 2025-2050 period. Significant changes in southern snow depth and increases in the length and temperature of the growing season should be evident by this period. Human CO_2 emission influences on climate warming will be the main driver of these trends and results could be experienced in the form of increasing thaw/refreeze damage in southern areas due to a lower snow pack, or increasing drought frequency in rain shadow areas such as the Miramichi. Although other authors identified that drought impacts on sugar maple east of Quebec City were rare in the past 100 years, the driest and most fire prone areas of the Maritimes could become more susceptible to drought.

With increasing temperatures, especially in winter, bioclimatic boundaries of pests and pathogens associated with sugar maple could disappear causing an escalation in biotic disturbances. Increasing levels of these normal background stressors of sugar maple in combination with unfavorable phases of the AMO and NAO could overcome certain individual trees of the normally disturbance resilient sugar maple species. Large but limited amounts of mortality could be possible in this scenario and large scale dieback within the crowns of sugar maple trees in this future time period should be expected. Variability in microclimate, site conditions, and maturity level of the trees may also play a large role in climatic injury susceptibility and radial growth rates of sugar maple. Consequently, we should expect uneven effects of climate change, pests, and pathogens on sugar maple trees across the landscape. This scenario could be far worse or not nearly as bad depending on human response to global climate change threats and changes in the concentrations of atmospheric CO_2.

The best projections indicate that sugar maple may be faced with substantial stress within 20 to 25 years. Increased incidence of mortality and dieback could be the outcome of this stress. The result could lower the number of trees and volume of sap available for maple syrup production. Potential mortality and crown dieback may also affect the aesthetic characteristics of the sugar maple population resulting in early leaf drop or brown leaves in some years. Due to the trends of damaging events, it appears at least a 10 to 15 year window of relatively beneficial climatic conditions is in store for sugar maple. This period offers a chance to produce more certainty in climate predictions, further the research regarding the comprehension of sugar maple response to damaging climate events, and develop mitigation efforts to lower the impacts of the worst case scenario.

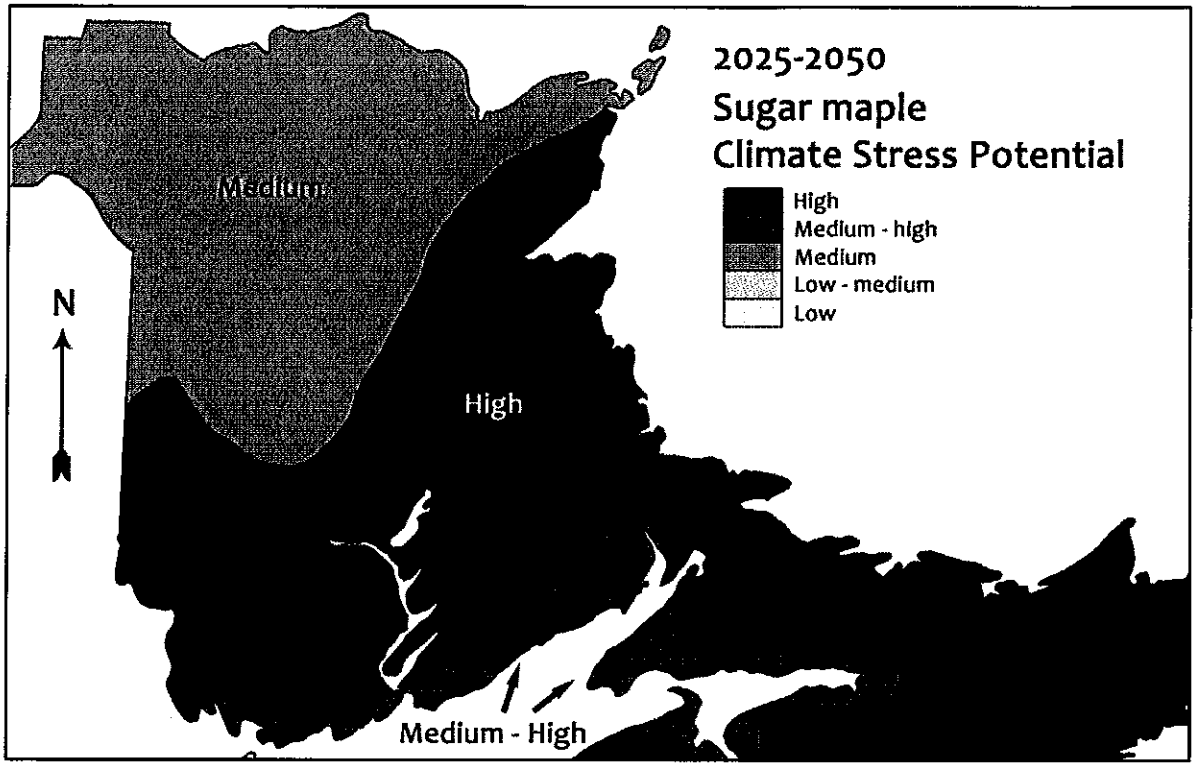

Figure 3. Climate stress potential map for sugar maple from 2024 – 2050.

Conclusion

The evidence used in this study suggests sugar maple health and radial growth rates should remain relatively stable over the next decade or more. Beyond 2025 sugar maple trees could encounter a less than an ideal set of growing conditions, climatic stressors and increasing incidence of insect and disease outbreak. A large amount of uncertainty surrounds these projections as the predictability of global human response to rising CO_2 concentrations and climate fluctuations themselves remains poor. Regardless of the current uncertainty, this study has raised important concerns for sugar maple trees based on scientific evidence. The future health of sugar maple trees may affect the number of trees and volume of sap available for future maple syrup production. Potential mortality and crown dieback may also periodically affect the aesthetic characteristics of the future sugar maple population. In light of these potential negative responses to climatic change, this study has identified a coming period of probable sugar maple health. This period will allow time for further study and development of mitigation and adaptation strategies.