How Will Climate Change Affect Maple Syrup?

Joshua Rapp, University of Massachusetts Amherst and Harvard Forest, Harvard University

Temperatures are rising globally, with 2015 the warmest year on record. Climate models predict that temperatures will continue to rise, although the magnitude of increase depends on how the global community chooses to respond. How might climate change impact maple syrup production, which is so intimately tied to the daily weather? Headlines are dire. An internet search reveals news articles titled: "All tapped out"; "Climate change not so sweet for sugar maples"; "Peak maple: climate change wants to ruin your pancakes"; "Goodbye maple syrup: climate change pushing sugar maple out of the northeast U.S." Maple syrup even makes a list of "Eight foods you're about to lose due to climate change."

State, regional, and national climate change assessments come to a similar conclusion. In 2014, the Vermont Climate Assessment (Galford et al. 2014) stated that "…climate change threatens VT's maple sugar industry due to … a decline in sugar maple health", while the U.S. National Climate Assessment (Melillo et al. 2014) stated, "…maple syrup producers…are…observing climate-related changes that are outside of recent experience." The New England Regional Assessment (New England Regional Assessment Group 2001) said, "…changes in climate could potentially extirpate the sugar maple within New England", while the Northeast Regional Assessment (Frumhoff et al. 2007) noted, "…warmer temperatures diminish the quantity and quality of sap flow and cause the tapping season to begin earlier and last less long."

The Acer Climate and Socio-Ecological Research Network (ACERnet) formed recently to study climate impacts on sugar maple and maple syrup production. With funding from the Department of Interior Northeast Climate Science Center, we are focusing our research on the relationship between sap quality and climate, and how producers can and are adapting to climate variability and change. With core sap collection sites from southern Virginia to northern Quebec, and Massachusetts to Indiana, we are collecting data on sap quality across a broad range of climate conditions. We are always interested in expanding our network of sap quality observations and data – from adding producer hosted sample collection sites to historical data, perhaps which is recorded on your sugar shack wall. We are also surveying maple syrup producers to understand how tapping seasons are changing and how producers respond to this change. What follows is the summary of a talk I gave during a workshop on "Sugar maple in a changing climate" held at the University of Massachusetts on December 7, 2015. To learn more about ACERnet and our project, and to get involved, please visit our website – blogs.umass.edu/acernet.

In this article I'll describe the main impacts of climate change on maple syrup production. These impacts can be put in to four categories: 1) availability of trees to tap; 2) tree health; 3) tapping season characteristics; and 4) sap quality and quantity.

Availability of trees to tap

Where a particular tree species grows is determined largely by environmental conditions. Soils, water availability and local topography all play a part, but climate is the ultimate filter. Paleoecologists who study the vegetation of the past by looking at pollen deposited in lakes, have seen that tree species ranges have changed as climate changed over thousands of years. At the end of the last ice age, for example, trees species moved north as the climate warmed. The current mix of tree species in a region reflects the climate of the past several centuries. Scientists have used this relationship between climate and tree species ranges to predict where tree species will live in the future. The USDA Forest Service maintains a "Climate Change Atlas" (http://www.fs.fed.us/nrs/atlas/) that shows how the habitat of 134 tree species in the eastern United States is predicted to change under various climate scenarios (Landscape Change Research Group 2014). The maps depict a reduction in sugar maple in most of its U.S. range by 2100. It is important to note here that these maps depict the suitability of habitat for sugar maple, and not the actual loss of trees. Trees can't pick up and move like animals, and individual trees can live a long time, up to 300-400 years for sugar maple. This means that many of the individual trees growing in the forest today will likely still be there in 2100, even if the habitat is less suitable for them.

In addition, for sugar maple to be pushed out of its current range, the trees will have to die and other species will move in. Seeds of these new spe-

Climate: continued on page 18

Climate: continued from page 17

cies will need to disperse from sites farther to the south, those seeds will need to germinate and the seedlings will need to establish and grow to the canopy to create the new forest. All of this takes time, and so far sugar maple seems to be holding its own. Mike Farrell has analyzed data from tree plots that are part of the U.S. Forest Service Forest Inventory and Analysis program (Farrell 2013). These data show that sugar maple of tappable size are increasing in the maple/beech/birch forest, while oaks and hickories, the predicted replacements of sugar maple, are actually decreasing. Another study found that sugar maple populations at the species' southern range limit have actually increased since 1990 (Hart et al. 2014). Both of these studies suggest that warming experienced so far has not affected the distribution of maple trees. From the available evidence, it looks like there will be sugar maples to tap for the next several decades at least. However, this should not be interpreted as evidence that sugar maple's range will be stable into the future. Data from the deeper past shows that eventually climate forces species to move.

Tree health

There may be trees to tap, but how healthy will those trees be? Maple producers and foresters have long been concerned with sugar maple tree health. In the 1980s, the North American Maple Project began monitoring sugar maple stands from Nova Scotia to Wisconsin (Allen et al. 1999). The overall project ran for 10 years, although monitoring was continued in some places like Vermont. The study revealed negative effects on sugar maple health from acid rain, insect pests, and other factors. Trees that are stressed by one factor may be more susceptible to another stressor, like a less favorable climate. Two predicted effects of climate change that could affect sugar maple health are a reduced winter snow pack and more frequent spring frost if trees respond to warmer temperatures by breaking bud earlier. A study by Daniel Comerford and colleagues showed removing the snow pack caused root dieback and reduced shoot growth in sugar maples (Comerford et al. 2013). Koen Hufkens and colleagues studied a widespread frost event in the northeastern U.S. in 2010 (Hufkens et al. 2012). This frost came after warm spring temperatures induced budbreak 2-3 weeks earlier than normal. The frost caused leaf-dieback in sugar maples across a wide area. The trees eventually put out new leaves in June, effectively making for a shorter growing season. Climate change effects on tree health and performance may vary across the range of sugar maple. Recent studies have shown growth declines in mature trees that may be related to climate change in the Adirondacks in recent decades (Bishop et al. 2015) while sapling height growth was positively related to temperature in the Great Lakes region (Fisichelli et al. 2015). More research is needed to clarify how climate affects tree health across sugar maple's range.

Tapping season characteristics

Climate change impacts on the tapping season are probably the most immediate and best understood effects. Maple syrup producers are already reporting that the tapping season is getting earlier and becoming more variable (Mozumder et al. 2015). Studies that use climate models to forecast the future tapping season predict these trends will continue, with the tapping season beginning 15-30 days earlier by

the end of the century, and becoming shorter, at least in the U.S. (Skinner et al. 2010 and Houle et al. 2015). So far however, improved technology, especially vacuum tubing systems, have resulted in increased sap yield per tap in recent decades, hiding any deleterious effects of a shorter or more variable season.

Climate change effects on sap quality

Less clear is how climate change may affect sap quality. Sap quality is determined by its sugar content and the secondary chemicals that create the distinct taste of maple syrup, making it more than just sugar water. Both sugar content and secondary chemistry are likely to be affected by climate change, but how exactly is not well known. One study reported that sap sweetness at one sugar bush in New Hampshire decreased over four decades, possibly related to climate change (Carlson 2013). However, average sap sweetness can be influenced by a number of factors including tree size, forest stand density, species mix, and use of vacuum for collection, so it's not clear how much of this trend might be related to climate. Even less is known about climate effects on secondary chemistry, although these chemicals are often produced in response to stress. If climate conditions become stressful for trees, they may produce more secondary chemicals, leading to darker, stronger syrup. Depending on market preferences, this may be a good or a bad thing for producers.

Conclusion

Climate change is likely to affect maple syrup production by influencing tree health, the timing and duration of the tapping season, the quality of sap, and ultimately the availability of trees to tap. ACERnet is working to understand these effects, especially the relationship between climate and sap quality. Please visit our website to learn more: blogs.umass.edu/acernet.

Literature Cited

Galford, Gillian L., Ann Hoogenboom, Sam Carlson, Sarah Ford, Julie Nash, Elizabeth Palchak, Sarah Pears, Kristin Underwood, and Daniel V. Baker, Eds, 2014: *Considering Vermont's Future in a Changing Climate: The First Vermont Climate Assessment*. Gund Institute for Ecological Economics, 219 pp.

Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2

Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA)*. Cambridge, MA: Union of Concerned Scientists (UCS).

New England Regional Assessment Group. 2001. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change. New England Regional Overview*, U.S. Global Change Research Program, 96 pp., University of New Hampshire.

Landscape Change Research Group. 2014. *Climate change atlas*. Northern Research Station, U.S. Forest Service, Delaware, OH. http://www.nrs.fs.fed.us/atlas.

Farrell, M. 2013. *The Sugarmaker's Companion: An Integrated Approach to*

Climate: continued on page 20

Climate: continued from page 19

Producing Syrup from Maple, Birch, and Walnut Trees, Chelsea Green Pub.

Hart, Justin L.; Oswalt, Christopher M.; Turberville, Craig M. 2014. Population dynamics of sugar maple through the southern portion of its range: implications for range migration. *Botany* 92: 563–569.

Allen, D.C, Molloy, A.W., Cooke R.R and Pendrel, B.A. 1999. A ten-year regional assessment of sugar maple mortality In: Horsley, S. B. and Long, R. P., eds. Sugar maple ecology and health: proceedings of an international symposium; 1998 June 2-4; Warren, PA. USDA Gen. Tech. Rep. NE-261. Radnor, PA.

Comerford, D.P., P.G. Schaberg, P.H. Templer, A.M. Socci, J.L. Campbell, and K.F. Wallin. 2013. Influence of experimental snow removal on the root and canopy physiology of sugar maple trees in a northern hardwood forest. *Oecologia* 171:261-269.

Hufkens, K., M. A. Friedl, T. F. Keenan, O. Sonnentag, A. Bailey, J. O'Keefe, and Richardson, A. D. 2012. Ecological impacts of a widespread frost event following early spring leaf-out. *Global Change Biology* 18:2365-2377.

Bishop, D. A., C. M. Beier, N. Pederson, G. B. Lawrence, J. C. Stella, and T. J. Sullivan. 2015. Regional growth decline of sugar maple (Acer saccharum) and its potential causes. *Ecosphere* 6:179. http://dx.doi.org/10.1890/ES15-00260.1

Fisichelli, N. A., A. Stefanski, L. E. Frelich, and P. B. Reich. 2015. Temperature and leaf nitrogen affect performance of plant species at range overlap. *Ecosphere* 6:186. http://dx.doi.org/10.1890/ES15-00115.1

Mozumder P, T.O. Randir, W.F. Vasquez, and M. Jerath. 2015. Risk perceptions and adaptation to climate variability: survey evidence from maple syrup farmers. *International Journal of Ecological Economics and Statistics*. 36(4):1-17.

Skinner, C. B., DeGaetano A.T., and B.F. Chabot. 2010. Implications of twenty-first century climate change on Northeastern United States maple syrup production: impacts and adaptations. *Climatic Change* 100:685-702.

Houle D., A. Paquette, B. Côté, T. Logan, H. Power, I. Charron, L. Duchesne. 2015. Impacts of climate change on the timing of the production season of maple syrup in eastern Canada. PLoS ONE 10(12):e0144844. doi:10.1371/journal.pone.0144844

Carlson, M. 2013. Monitoring the health of the sugar maple, Acer saccharum. Doctoral dissertation. University of New Hampshire.