Maple Syrup

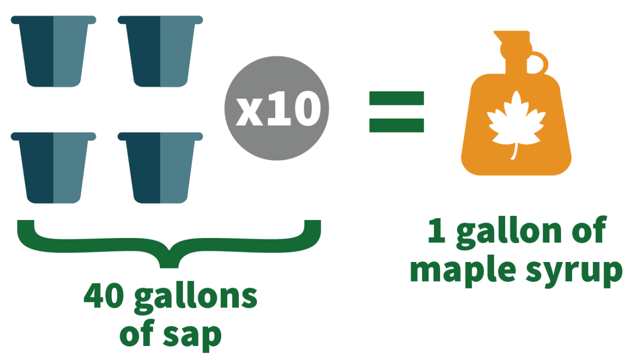
Preparer

Kristen Giesting, USDA Northern Forests Climate Hub-NRCS Liaison

Introduction

Maple syrup is produced from the sap of maple trees, which is collected from late winter through early spring. The collected sap is clear and only slightly sweet; to produce syrup and sugar, the sap must be concentrated through evaporation (boiling) or reverse osmosis.

During the growing season, maple trees store starch in their sapwood (an outer layer of wood within the tree's trunk). When the temperature of the wood reaches approximately 40°F, the starches are converted into sugars, which pass into the sap. When a tap hole is drilled, the sap-carrying vessels are severed, allowing the sap to flow out for collection (1). Sap flow is heavily weather-dependent, with temperature fluctuations creating pressure within the tree to move the sap. Among maple producers, it is well-known that spring temperatures must fall below freezing (usually at night) and rise above freezing (usually during the day), for sap to flow. After a freeze-thaw event, sap can continue to flow for 30-72 hours. The season typically lasts 4-6 weeks and ends when temperatures remain above freezing and buds begin to break dormancy (2). Under ideal conditions, a single tap hole can yield 40-80 gallons of sap in a season, although a more typical average is between 5-15 gallons (1). Sugar content of the sap varies widely among individual trees, but generally averages 2-3%; thus, it takes approximately 40 gallons of sap to yield one gallon of maple syrup (3, 1). Sugar maple (*Acer saccharum*) is the primary species targeted, but red maple (*Acer rubrum*) and other maples also produce sugary sap.



In 2017, maple syrup production was a $147 million industry in the United States, with 4.27 million gallons produced from approximately 13.3 million taps. In the United States, maple production primarily occurs in New England and the Midwest. Vermont, New York, and Maine are the top-producing states currently (4), while Michigan, Pennsylvania and other states have an even larger amount of potential maple resource that could be tapped (5). Due to the weather-dependent nature of sap flow, climate change is likely to have significant impacts on the maple industry. These impacts will be geographically dependent; some areas will see a loss in ability to produce any appreciable quantity of syrup, while other areas will see increases in sap flow and overall yield (3, 6, 7, 8, 9, 10).

Issues

Maple trees are a major component of northeastern mesic forests and provide multiple ecosystem services; maple syrup is an iconic and highly valued non-timber forest product with a particularly strong cultural presence in New England. Native Americans have a long history of producing maple sugar, a tradition which was adopted by early settlers. In recent years, the demand for maple products has been on the rise (5, 6, 11). The timber value for maple is also high; however, this use is not considered compatible with syrup production due to the damage caused by drilling tap holes into the trunk (6, 11), except for small niche markets for specialty lumber that are not well developed.

Sugar maple is a sensitive species and has experienced climate-related decline historically (7). The observed declines may occur for several reasons: insects, drought, or freeze-thaw events. It has been observed that even subtle disturbances will tend to favor the beech component within the maple-beech ecosystem (12). Maple is also susceptible to other ecosystem challenges including air pollution (e.g. acid rain, ozone) and invasive species (e.g. Asian Long-horned beetle) (11). Additionally, because maples are one of the first species to break bud in the spring, they are particularly vulnerable to damage from late frost events (7). Challenging conditions for syrup production may lead to low-yield years, negatively impacting producers and contributing to instability in supply to the market (10).

Likely Changes

Under a high emissions scenario, sugar maple is projected to lose suitable habitat in southern and southwestern portions of its range, while maintaining habitat in northern and northeastern areas. However, sugar maple is a long-lived species, and a decline in suitable habitat does not necessarily mean an immediate decline in abundance of this species (6). The risk for this species is very geographically dependent (6, 7); future opportunities for expanded production may exist in the Great Lakes region (8), and sap production may also increase in northern Maine and parts of Ontario and Quebec. Under a high emissions scenario, the maximum sap flow region is projected to move 400km to the north by 2100 (3).

Changing spring conditions and warmer winter temperatures will likely cause the sap collection season to shift and shorten, particularly in the southern parts of maple's range, as the freeze-thaw season moves earlier in the year (6, 10). In one study, 59% of maple producers indicated they have already seen earlier tapping seasons (13). The early arrival of spring has a negative impact on the industry, as this can shorten the sap season by inducing early bud break. Warm temperatures can also increase the growth of microorganisms, leading to the premature clogging of tap holes (9). By the end of the century, under a high emissions scenario, the midpoint of the sap collection season is predicted to occur a month earlier (3).

Warmer winter temperatures are likely to result in decreased snowpack in areas where it was once common. With snowpack missing, soil is more likely to freeze, leading to increased mortality and turnover in fine roots (14, 15). Increased soil frost depth and duration has also been shown to have detrimental effects on the aboveground growth in sugar maples, which may have negative implications for carbon storage in forests (16). One study demonstrated a 40% reduction in aboveground growth due to increased soil freezing, which resulted in an estimated 8.8% decrease in forest carbon storage, for forests that are adapted to snowpack conditions. Perhaps the longer growing seasons expected in the future could serve to mitigate these losses. Also, sugar maple exists in a broad geographic range, including areas which do not experience regular snowpack; perhaps trees will have the capacity to acclimate to changing snow conditions over time (14).

It is not only warmer temperatures in winter that may be problematic for sugar maple. Warmer summer temperatures have been linked to decreased sugar content in the subsequent sap season. As temperatures warm, a tree's rate of respiration increases faster than its rate of photosynthesis, which impacts the tree's carbon storage, and thus, the sugar content for the following sap season. For every 1°C increase in the previous May through October temperature, sap sugar content has been shown to decline by 0.1°Brix. Historically, the sap sugar content is 2°Brix or higher; under a high emissions scenario, Brix is projected to drop an average of 0.55-0.65° by end of century. Overall, sugar content is expected to be lower and more variable in the future (3).

Syrup producers are also concerned about the impacts that extreme weather events, such as wind and ice storms, may have on the health of their sugarbushes (17). In adapting the maple industry to climate change, it will be important to utilize and promote adaptation strategies that can meet immediate as well as long term needs (11).

Options for Management

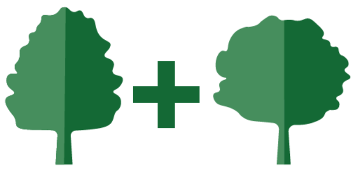
There are numerous management possibilities to maintain syrup production into the future, although adaptation measures will likely differ depending on geography (13). Under a high emissions scenario, syrup yields are expected to drop, potentially necessitating a 4.9 million tap increase to maintain current production levels (6). Adding additional taps, as well as utilizing advances in technology and infrastructure, such as plastic tubing and vacuum systems, may allow for more sap to be collected (3, 6, 9, 13). Improved sanitation practices can also improve yields (9) by minimizing microorganism growth and preventing sap contamination during periods of warmer temperatures (13).

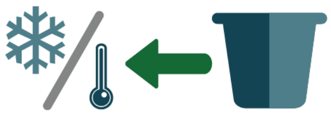
Although sugar maple (*Acer saccharum*) is the preferred species for syrup production, other *Acer* species, such as red maple, are also suitable to collect sap from, though the concentration of sugar is generally lower. This may be a useful adaptation strategy, as red maples are projected to maintain a wider range of suitable habitat into the future (6).

Shifting the sap season up, to take advantage of earlier freeze-thaw events, is another possibility for climate adaptation (6, 8, 13). However, this strategy is only viable up to a certain point; as climate change continues to progress into the next century, it will be impossible to continually move the sap season earlier, and syrup production will decline in many parts of its range. This will likely be true during this century for areas from central Pennsylvania and southward (18). However, some areas will likely see increases in maple syrup production, including parts of Maine, Canada (3), and the Great Lakes region (8). Maintaining maple in climate refugia is another possibility (7).

Silvicultural practices to support maple health may also be useful to consider. For example, maples with large, spreading crowns and less competition produce more and sweeter sap (1, 2, 9). Additionally, sugar maples have high soil fertility requirements; thinning is a good practice to reduce competition for this resource (2). Prior to undertaking thinning, it may be advisable to test the sugar content of individual trees, as "sweetness" appears to be an individual characteristic that is consistent across years (19). Finally, there are many maple trees in the next size class; this may signal an opportunity for expanding maple production, when these trees reach an appropriate size for tapping (6).

Some maple syrup producers are already beginning to think about climate change adaptation in their sugarbushes, with larger scale producers appearing more likely to be implementing adaptation strategies (8). Although many maple producers have an intention to engage in adaptation for their sugarbush (8), barriers to implementation remain a problem. Barriers may include a lack of access to information, a need for technical support (13), as well as the costs associated, the long lifespan of the trees, and a lack of research on the topic (11). A lack of belief in climate change or uncertainty of impacts on maple is also a limiting factor for some (11, 13). Adaptation actions that resonated with the most producers included implementing new technology and active tree management (8, 11).





From an industry adaptation perspective, 70% of maple producers would like to see the promotion of late season or “buddy” syrup (so-called due to the off flavor which develops as the trees break bud), which is currently not marketable due to industry quality standards, but has potential for use as a nutraceutical or sweetening agent. And while many producers (62%) are supportive of the industry developing future-adapted maple varieties, most producers are not particularly supportive of moving sugar maples further north via assisted migration (13).

How to cite

Giesting, K. 2020. Maple Syrup. USDA Forest Service Climate Change Resource Center. www.fs.usda.gov/ccrc/topics/maple-syrup

Recommended Reading

1. Rapp, J.M.; Lutz, D.A.; Huish, R.D.; Dufour, B.; Ahmed, S.; Morelli, T.L.; Stinson, K.A. 2019. Finding the sweet spot: Shifting optimal climate for maple syrup production in North America. Forest Ecology and Management. 448: 187-197.
2. Matthews, S.N and Iverson, L.R. 2016. Managing for delicious ecosystem service under climate change: can United States sugar maple (*Acer saccharum*) syrup production be maintained in a warming climate? International Journal of Biodiversity Science. 13(2): 40-52.
3. Legault, S.; Houle, D.; Plouffe, A.; Ameztegui, A.; Kuehn, D.; Chase, L.; Blondlot,A.; Perkins, T. 2019. Perceptions of U.S. and Canadian maple syrup producers toward climate change, its impacts, and potential adaptation measures. PLoS ONE. 14(4): e0215511.
4. Skinner, C.B.; DeGaetano, A.T.; Chabot, B.F. 2009. Implications of twenty-first century climate change on Northeastern United States maple syrup production: impacts and adaptations. Climatic Change 100: 685-702.

Related Links

1. Maple syrup production resources from the University of Maine extension. https://extension.umaine.edu/maple-syrup-production/
2. Cornell Maple Program: Sugar Maple Research and Extension. http://blogs.cornell.edu/cornellmaple/

Research

1. Sugar Maple Regeneration: Citizen Science

A citizen science partnership between Hubbard Brook Experimental Forest and the Society for the Protection of New Hampshire's Forests, supported by the USDA Northeast Climate Hub, seeks to investigate issues surrounding sugar maple regeneration.

2. Acer Climate and Socio-Ecological Research Network (ACERnet)

Research group studying the impacts of climate change on sugar maple and maple syrup production. They are monitoring sap flow across sugar maples' range, from Virginia to Quebec, and are seeking to understand how climate change may impact sap flow, sugar content, and chemical composition.

3. Proctor Maple Research Center at the University of Vermont

The Proctor Maple Research Center conducts basic and applied research on numerous aspects of maple tree health and syrup production.

References

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