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Maple Syrup Producers of the Lake States, USA: Attitudes Towards and Adaptation to Social, Ecological, and Climate Conditions

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Abstract
Maple syrup is an important non-timber forest product derived from the sap of the sugar maple (*Acer saccharum* Marshall). However, maple syrup producers are facing a diversity of challenges, including: potential range shifts in the maple resource; increasing variability in the timing, duration and yield of sap flow and syrup operations; invasive species, pests and diseases; and intergenerational land and business transfer challenges. Members of Maple Syrup Producer Associations in Minnesota, Wisconsin, and Michigan were surveyed to learn about their operations, adaptation strategies, concerns, and information needs. While many respondents indicated they have undertaken or plan to undertake adaptation activities, only 11% had done so out of specific concern over changing climate conditions. Climate-motivated activities included: being prepared to tap earlier and utilizing newer technology such as vacuum tubing or reverse osmosis to enhance sap collection and processing efficiency. Respondents were generally unlikely to consider planting climate-resilient maple cultivars or tapping trees other than sugar maple. They expressed the greatest concerns over tree health and forest pests, as well as their physical ability and family member interest to continue their operations. Boil season variability and weather issues were viewed with less concern. Respondents were generally optimistic that they can adapt to future conditions, likely in large measure through the adoption of new technologies, and they expect their syrup production levels to slightly increase in the future. If future climate scenarios play out, however, additional planning and adaptation strategies may be called for, particularly as they relate to forest health and productivity issues.

Keywords Family forest landowner · Non-timber forest product (NTFP) · Sugar maple · Climate adaptation · Sugaring · Non-industrial private forest landowner (NIPF)

Introduction

Maple syrup is an iconic economically and culturally important non-timber forest product (NTFP) of northeastern North America. Produced largely from sugar maples (*Acer saccharum* Marshall), the economic benefits derived from maple syrup production are substantial. In 2016, the United States produced 4.2 million gallons of syrup worth an estimated $147 million (USDA 2017). In addition, sugaring provides many producers with a personal connection to forestland, a means to develop social capital and support rural identity, and a way to keep a family or cultural tradition alive (Hinrichs 1998; Murphy et al. 2012). Yet, producers of maple syrup in the United States are currently facing a diversity of challenges, including potential shifts in the range of suitable habitat for sugar maple; increasing variability in the timing, duration and yield of syruping operations; threats to the maple resource from invasive species, pests and diseases; intergenerational land and business transfer challenges; high syruping equipment costs; forestland property tax burden; and competition from Canadian syrup producers (MacIver et al. 2006; Farrell 2009; Skinner et al. 2010; Mathews and Iverson 2017). In light of these challenges, we were interested in learning about maple syrup producers' awareness of, attitudes toward, and concerns on how these factors may be affecting

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their sugar bush and syrup operations, as well as whether or how they may be responding and adapting their operations in the face of these pressures.

Given that maple syrup production is strongly tied to weather conditions, climate variability and related stressors influence syrup production (MacIver et al. 2006; Duchesne et al. 2009; Farrell 2009; Mathews and Iverson 2017). Syrup is derived from the sugar in the sap which trees produce and store as starch in their roots during the winter. Sap can be extracted in the spring when pressure differentials created by below-freezing night time temperatures followed by above-freezing day time temperatures cause sap to flow. Changes in winter temperatures and conditions impact timing, continuity, and duration of sap production. In general, increases in average winter temperatures are anticipated to result in a reduction in the number of sap flow days and/or a shift in the sap collection season (Duchesne et al. 2009; Skinner et al. 2010). In addition to temperature, sap production is also influenced by soil moisture, tree health, and snow pack (Skinner et al. 2010); factors which are influenced by climatic parameters. For example, decreased sap flow and quality has been associated with drought (Foster et al. 1992). Climate variability is also anticipated to have impacts on sap volume, sugar content, and quality, although research is needed to explore the specific nature of these relationships (Skinner et al. 2010). Models suggest the range of the sugar maple habitat may shift northward in the future, contracting at its current southern reaches (Prasad et al. 2007; Iverson et al. 2008; Mathews and Iverson 2017). Taken together, climatic stressors may require maple syrup producers to actively adapt their operations (Mathews and Iverson 2017). Biological threats to the sugar maple resource are also emerging and/or may expand their range in the future. Examples which may pose threats in the future to the Lake States include invasive pests such as the Asian Longhorned beetle (*Anoplophora glabripennis*), which has been found to have particular affinity for sugar and red maples (Dodds and Orwig 2011), and the fungus *Ceratocystis coerulescens* which causes the fatal Sapstreak disease in sugar maples (Bal et al. 2013).

Finally, many of those who produce maple syrup, at least on a small scale, are also family forest landowners (Whitney and Upmeyer 2004). As such, this segment of producers faces a spate of challenges associated with being a private forest landowner (Butler et al. 2016). For some, this includes concern about their physical ability to continue operations given that the average age of family forest landowners in the U.S. is 63 years old (Butler et al. 2016). Related to the aging landowner base, succession planning and concerns about whether heirs are interested in maintaining a syruping operation or even keeping forestland intact are issues that forest landowners are increasingly confronted with (Withrow-Robinson et al. 2013). Taxes on private forestland (Butler et al. 2012), as well as parcelization (Mehmood and Zhang 2001) and land development pressures (Stein et al. 2005) also exert influence over forest landowner decision-making for the use and future of private forestland.

The bulk (64%) of maple syrup production in the United States occurs in Vermont and New York (USDA NASS 2016). However, some upper Midwestern states produce marketable quantities of maple syrup products, as well. Specifically, according to the National Agricultural Statistics Services (NASS), in 2016 Wisconsin produced 235,000 gallons of maple syrup, Michigan 90,000 gallons, and Minnesota 14,000 gallons (USDA NASS 2016). Research suggests significant potential for increasing the percentage of sugar maple trees that could be tapped in this region, particularly in Michigan (Farrell 2009; Mathews and Iverson 2017). In addition, recent research on the potential impacts of future climate conditions on the sugar maple resource has suggested that Minnesota may see enhanced habitat suitability for sugar maple under future climate scenarios, also indicating expansion potential for the syrup industry in this region (Iverson and Matthews 2018).

Given these optimistic indicators for the maple syrup industry in the Lake States of Minnesota, Wisconsin, and Michigan, we suggest that the producers in the Lake States could be an important segment of this industry. We believe a study focused on producers in the Lake States would provide new insights into the maple industry and maple producers in a region of the country and maple sugar range that has opportunities for enhanced production levels under current and potential future climate conditions. Findings from this study can contribute to the development of assistance, research, outreach, and educational programs to help maple syrup producers understand, plan for and adapt to changing conditions and challenges.

Background

Increasing climate variability will have wide ranging implications for non-timber forest products of all sorts, including sugar maple. Among these are changes in historical distributions of species and timing of key life cycle phases, creating challenges for the people who depend on them (Chamberlain et al. 2018). While there is a substantial body of literature on the ecological aspects of maple syrup production (Farrell 2013) and the response of the sugar maple resource itself to changing climate (e.g., Iverson and Prasad 2002; Skinner et al. 2010; Iverson and Matthews 2018), much less is known about the producers of maple syrup. The research on maple syrup producers has largely focused on two issues: (1) performance of or need for extension programming for maple syrup production, and (2) barriers and attitudes towards increased tapping and production. Producers have been surveyed in Pennsylvania (Demchik et al. 2000) and Ohio (Graham et al. 2006, 2007) about their needs for and attitudes towards information, assistance, and outreach programs. In research on barriers to syrup production, Farrell and Stedman (2013) identified concerns about the impacts of tapping on the value of sugar maple sawtimber; lack of time, available labor, interest and knowledge in the sugaring process; and perceived lack of accessible maple trees. Other research has focused on understanding the social and cultural significance of maple syrup production (Hinrichs 1998; Whitney and Upmeyer 2004).

A topic that is largely missing from the literature is an examination of maple syrup producers' attitudes and behaviors relative to ecological and climate stressors and associated adaptation planning. The scant research on this topic includes a small study ($n = 33$) on the impacts, adaptation opportunities, and adaptive capacity of syrup producers who attended a maple syrup conference in Ontario (Murphy et al. 2012). Results of this analysis found that while the majority of producers (70%) believed climate change had or will impact their syrup operation in the future, little direct action had been undertaken specifically in response to climate change.

The only other study on this topic examined knowledge and perceptions of climate change by commercial maple syrup producers in New York and Vermont, as well as their perceptions on their ability to adapt to climate-change related impacts (Kuehn et al. 2016, 2017). In this research, over half of respondents (58%) had at least one concern related to climate change and its potential impact on their syrup operation. Damage to their sugar bush from extreme weather events was the most commonly mentioned topic of concern (14% of respondents), followed by concerns for an earlier tapping season or change in timing for sap collection (13% of respondents). When asked about the types of changes they thought would be needed to their maple operation in the future or already undertaken in response to climate change, 66% of respondents indicated they had made or were planning to make modifications to their operations due to climate concerns. The most frequently cited adaptation activity already taken was tapping earlier, followed by having added a vacuum tubing system to increase production. All other adaptation activities that were mentioned were cited by 5% or less of respondents, including: improving tree health, increasing the number of taps, and installing new technologies such as reverse osmosis. Our research adds to this study by examining maple syrup producers' attitudes towards ecological, economic, social, and climate-related factors facing their operations and adaptation planning in a different part of the United States.

Methods

Our study population consisted of members of the Maple Syrup Producers Associations (MSPAs) in Minnesota, Wisconsin, and Michigan. These three states share many similarities in terms of tree species and landowner characteristics. The MSPAs are non-profit organizations focused on providing information and education about extracting, processing, and/or marketing maple syrup and associated products. Membership is open to any size operation. Minnesota and Wisconsin provided contact information for all of their current members. Michigan maintains two levels of membership: hobby producers (defined as those who produce syrup for use by family and friends, and/or sell a small amount, and/or simply have an interest in maple syrup production) and commercial producers (defined as those who produce, pack or prepare any maple product for profit). We only were able to obtain contact information for Michigan's commercial producer members. No comprehensive database of maple syrup producers is maintained by any other organization in our study region.

A mail-back questionnaire was developed to gather information about a respondent's: (a) sugaring operation, (b) motivations for and attitudes towards producing maple syrup, (c) observations of and attitudes towards threats and changes they are experiencing in their operations, (d) actions they may be taking or willing to take in response to these threats and changes, (e) information needs, and (f) demographics. The survey was pre-tested in June 2016 by seven individuals who had experience sugaring in Minnesota, Wisconsin or Iowa, but who were not members of a MSPA. Based upon their feedback, the questionnaire wording was slightly modified to enhance its clarity. This revised version of the survey was reviewed by two of the same individuals for a second pre-testing in July 2016 to ensure that the modifications had successfully captured their suggestions.

Following the Dillman tailored design method (Dillman 2000), a total of five contacts were made with potential respondents between August and October 2016: a pre-notice postcard, questionnaire, reminder postcard, second questionnaire, and a final email correspondence (when an email address was available through the membership list). Of the 464 surveys that were mailed (183 to MN members, 85 to MI members, and 196 to WI members), six were returned as undeliverable, and 354 responses were received for an overall response rate of 77% (148 from MN, 59 from MI, and 146 from WI). The usable response rate was 73%.

To check for nonresponse bias, the initial quartile of respondents (based on when the completed questionnaire was received) was compared to the last quartile following Armstrong and Overton (1977). *T*-tests and chi-square tests revealed that late responders were slightly more likely to be MI members, and early responders were slightly more likely to be MN members ($\alpha = 0.05$). However, no significant differences were found between early and late responders relative to equipment type, production levels, operation size, acres of forestland owned, future plans for their operation, or years of syrup operation. The only other significant variable found was the year in which the respondent was born; late responders were slightly younger than early responders with an average birth year of 1960 for late responders versus 1955 for early responders ($\alpha = 0.05$). By virtue of their voluntary membership in a MSPA, we suggest our study population may be a more knowledgeable and engaged segment of maple syrup producers than the average Lake States producer. Our results should be interpreted with this point in mind.

Descriptive statistics were produced for many of the survey questions segmented by state and/or producer size class (i.e., number of taps). Comparative analyses by producer size class were computed for some of the survey questions using χ^2, ANOVA with post-hoc Tukey tests, and cumulative logit models, as appropriate, to the data type.

A total of 175 individuals responded to open-ended questions and/or spontaneously offered comments by writing in the margins or at the end of the survey. These qualitative data were analyzed using a modified conventional content analysis approach to identify themes in the comment text. A coding scheme was developed based on these emergent themes and a priori categories determined by the survey design (Hsieh and Shannon 2005). The coding scheme was then applied to a sample of the qualitative data by three members of the research team and further refined. The full narrative data set was coded and analyzed by a single member of the team using qualitative data analysis software (NVivo 10; QSR International 2012). Selected results of this analysis are reported following quantitative analysis topics, illustrated by representative quotations.

To facilitate analysis, three producer size categories were created based on the number of taps utilized for the 2016 season. While there are no industry-standards of what defines a producer size class, our intent was to create classes that approximate small, medium, and large operations in the Lake States with the idea that behaviors, needs and concerns might vary by the size of one's operation. Other studies of maple syrup producers have also segmented by different metrics of operation size reflective of the study objectives and range of producer sizes in the study region (Demchik et al. 2000; Graham et al. 2007, Farrell and Stedman 2013). We received advice from an officer in the Minnesota MSPA (Stephen Saupe, Personal Communication, 3/23/17) and examined the literature (Graham et al. 2007) to help us determine how to segment producer size class by number of taps, arriving at the following three size categories: (1) small producers (S) were defined as those with less than 100 taps, (2) medium producers (M) were defined as those having between 100 and 1000 taps, (3) large producers (L) were defined as those with greater than 1000 taps. The distribution of respondents by the three producer size class reveals that 18% of respondents were S producers, 48% were M, and 33% were L size operations. In spite of the fact that the Michigan MSPA list we obtained was identified as their commercial producer list, 11% of the Michigan respondents were in our S category, 36% in M category and 53% in our L category.

Results

Socio-Demographic Factors

The age of respondents ranged from 19 to 89, with an average age of 60 for the sample. The average age of the respondent varied significantly by producer size class [$F(2, 296) = 9.52$, $p < 0.001$]. Large producers are somewhat younger than S and M producers (64 years for S producers, 62 for M producers and 56 for L producers). Ninety percent of respondents were men, and 99% were white, not of Hispanic or Latino origin, with no statistical variations among the producer size classes for these two attributes. One respondent identified themselves as Native American. The majority of respondents, regardless of producer size class, have a residence (either a primary or secondary home) at their sugar bush property (78, 75, and 74% for S, M and L respondents, respectively). No statically significant differences in residence relative to sugaring site were found between producer size classes (χ^2 (2, $N = 304$) $= 0.44$, $p = 0.80$).

Actions Taken Specifically Out of Concern for Changing Climate Conditions

Respondents were asked whether they had undertaken any actions or plan to take any actions in the next 10 years specifically out of concern for changing climate conditions. Overall, 11% of respondents indicated in the affirmative to this question (6% of S, 10% of M, 15% of L producers). An open-ended question asked respondents to write-in specific actions they have taken or plan to take out of concern for changing climate conditions. Preparations to tap early and changes in technology were the most commonly mentioned climate change adaptation action.

[It is] Less of an action but more of a mindset. We make sure our schedules accommodate earlier sugaring seasons. And have planned less sugarbush work prior to the season to be sure to be ready for an early season.
(Minnesota, Large)

This question also elicited comments that explicitly or implicitly address whether respondents believe anthropogenic climate change is occurring. These fifteen comments were roughly evenly divided between those who do and do not:

Don't believe in it (climate change).
(Wisconsin, Medium)

Climate change will pose new challenges.
(Michigan, Large)

Perceptions of Trends in Sap Season Characteristics

Respondents were asked their perceptions of trends in six factors associated with sap season conditions and syrup production over the past 10 years: (1) sap production per tap, (2) sugar content, (3) start of boil season, (4) end of boil season, (5) length of boil season, and (6) continuity of sap run. Respondents who reported owning their syrup operation less than 10 years were not included in the analysis of this question, resulting in 78 responses being dropped for this section of the analysis. Questions in this section were designed to gauge perspectives on whether the respondent perceived directionality of a trend, no trend, or uncertainty about a trend (Tables 1–6). When examining the data across all producer size classes, 'no change' was the most common response chosen for five of the six factors. For example, when queried about the end of the boil season, 52% of respondents indicated no change in timing over the past 10 years, 28% indicated an earlier end, 17% a later end, and 3% were uncertain. The exception was the question related to potential trends in the start of the boil season, with 47% reporting the trend was toward an earlier start date and 44% indicated no change. Thus, over the past 10 years, respondents generally perceived no trends in the temporality of syrup season characteristics.

Chi-square tests were undertaken to determine whether perceptions of sap season trends varied by producer size class. For three of the syrup production trends, perceptions about boil start date ($\chi^2(6, 224) = 5.2733$, $p = 0.5093$), boil end date ($\chi^2(6, N = 219) = 8.3879$, $p = 0.2110$), and boil season length ($\chi^2(6, 221) = 8.1082$, $p = 0.2303$) were not

Table 1 Perceptions of trend in sap production per tap over the past ten years (percentage of respondents by producer size class)

Producer size class	Lower ($N = 26$)	No change ($N = 96$)	Higher ($N = 80$)	Don't know ($N = 20$)
Small ($N = 37$)	11%	65%	14%	11%
Medium ($N = 101$)	15%	47%	24%	15%
Large ($N = 84$)	8%	30%	61%	1%
Overall	12%	43%	36%	9%

Global χ^2 test indicates statistically significant differences among responses as a function of producer size class ($\chi^2(6, N = 222) = 42.7644$, $p < 0.0001$)

Table 2 Perceptions of trends in sugar content over the past ten years (percentage of respondents by producer size class)

Producer size class	Lower ($N = 43$)	No change ($N = 136$)	Higher ($N = 21$)	Don't know ($N = 24$)
Small ($N = 38$)	13%	55%	13%	18%
Medium ($N = 102$)	14%	60%	11%	16%
Large ($N = 84$)	29%	64%	6%	1%
Overall	19%	61%	9%	11%

Global χ^2 test indicates statistically significant differences among responses as a function of producer size class ($\chi^2(6, N = 224) = 19.9513$, $p = 0.0028$)

Table 3 Perceptions of trends in start of boil season over the past ten years (percentage of respondents by producer size class)

Producer size class	Earlier ($N = 103$)	No change ($N = 96$)	Later ($N = 15$)	Don't know ($N = 4$)
Small ($N = 38$)	47%	39%	8%	5%
Medium ($N = 100$)	48%	42%	8%	2%
Large ($N = 80$)	46%	49%	5%	0%
Overall	47%	44%	7%	2%

Global χ^2 test indicates no statistically significant differences among responses as a function of producer size class ($\chi^2(6, 224) = 5.2733$, $p = 0.5093$)

Table 4 Perceptions of trends in end of boil season over the past ten years (percentage of respondents by producer size class)

Producer size class	Earlier ($N = 62$)	No change ($N = 113$)	Later ($N = 37$)	Don't know ($N = 7$)
Small ($N = 38$)	39%	37%	16%	5%
Medium ($N = 100$)	26%	52%	19%	3%
Large ($N = 81$)	26%	58%	15%	1%
Overall	28%	52%	17%	3%

Global χ^2 test indicates no statistically significant differences among responses as a function of producer size class ($\chi^2(6, N = 219) = 8.3879$, $p = 0.2110$)

Table 5 Perceptions of trends in length of boil season over the past ten years (percentage of respondents by producer size class)

Producer size class	Shorter ($N = 46$)	No change ($N = 121$)	Longer ($N = 43$)	Don't know ($N = 9$)
Small ($N = 38$)	29%	45%	18%	8%
Medium ($N = 98$)	24%	52%	19%	4%
Large ($N = 83$)	13%	64%	21%	2%
Overall	21%	55%	20%	4%

Global χ^2 test indicates no statistically significant differences among responses as a function of producer size class ($\chi^2(6, 221) = 8.1082$, $p = 0.2303$)

Table 6 Perceptions of trends in continuity of sap run over the season over the past ten years (percentage of respondents by producer size class)

Producer size class	Less ($N = 56$)	No change ($N = 114$)	More ($N = 28$)	Don't know ($N = 18$)
Small ($N = 38$)	39%	42%	3%	16%
Medium ($N = 97$)	26%	55%	12%	7%
Large ($N = 81$)	20%	56%	19%	6%
Overall	26%	53%	13%	8%

Global χ^2 test indicates statistically significant differences among responses as a function of producer size class ($\chi^2(6, N = 216) = 13.1014$, $p = 0.0415$)

found to vary as a function of producer size class. Differences in responses towards the other three factors did vary by size class, although not in consistent ways.

Write-in comments allowed producers to share more nuance about their observations of sap season conditions. Among respondents offering comments regarding timing, a trend toward an earlier beginning was noted. However, this observation was not mutually exclusive of statements that, like the weather, respondents' seasons remain highly variable from year to year:

> Has usually been in March, this year was end of January.
> (Michigan, Large)

> Difficult to answer, all depends on weather. Trend is toward warmer, earlier seasons.
> (Minnesota, Small)

Taken as a whole, comments on volumes of sap and syrup confirm perceptions of seasonal variability, with no discernible perception of trends in production from year to year:

> Sometimes you invest a lot of time and energy to get a good amount, other times you have 120 taps out and the weather doesn't cooperate and you end up with two quarts of syrup, but that's life.
> (Minnesota, Small)

Adaptation Activities—Already Undertaken

Respondents were asked to think about the future of their syrup operation and specify the likelihood that they would undertake any or all of eight adaptation activities in the next ten years, as well as if they had already undertaken these activities. Overall, the activity undertaken to date by the greatest percentage of respondents was adopting new technology (26%), followed by managing for healthier trees (18%), product diversification (18%), and managing for more productive trees (17%). The activities with the lowest percentage of implementation across all respondents were planting climate-resilient maple trees (1%), product simplification (1%), and tapping non-sugar maples (4%) (Fig. 1).

For three of the activities, no statistically significant differences were found (planting climate change resilient maple trees, maple product simplification, tapping trees besides sugar maple) across producer size classes. For the other five activities, levels of implementation statistically differed by producer size class: adopting different sugaring technology ($\chi^2(2, N = 304) = 28.8320$, $p < 0.001$), active management for more productive trees ($\chi^2(2, N = 305) = 6.9166$,

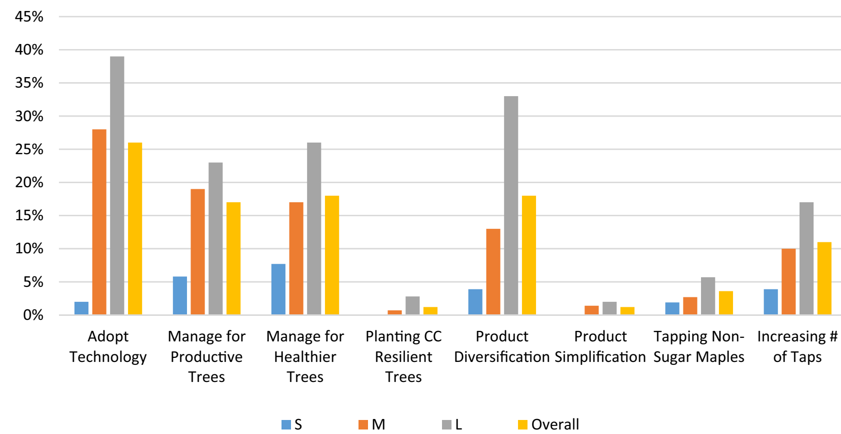

Fig. 1 Adaptation activities already undertaken by producer size class (percentage of respondents)

$p = 0.0315$), active management for healthier trees ($\chi^2(2, N = 305) = 7.7039$, $p = 0.0212$), product diversification ($\chi^2(2, N = 305) = 25.400$, $p < 0.0001$), and increasing number of taps ($\chi^2(2, N = 304) = 6.2433$, $p = 0.0441$). In general, S producers reported low levels of implementation across all of the queried activities.

Written comments regarding sap collection technology as an aspect of adaption planning were offered by 32 respondents. Of these, nearly half mentioned vacuum technology and, in particular, obtaining steadier and increased flow over yield from older approaches, with one respondent noting this may mask climate change effects:

> Our enhancements to the sap collection methods (tubing/vacuum) have led to significant increases in the amount of sap collected and maple syrup made. This technology improvement will skew the numbers (and may not really show the impact of climate change.)
>
> (Minnesota, Large)

While the adoption of tubing and vacuum technology generally is regarded as a positive measure, some respondent comments note actual or potential problems resulting from their operation's switch to vacuum technology. In addition to the potential for excess production, some stated that damage to vacuum lines and costs associated with restoring them following large wind and ice storms may increase in frequency and/or severity under future climate conditions.

> Now that we have vacuum lines, we are flooding the market.
>
> (Wisconsin, Large)

> In July 2016 we had a bad wind storm…that damaged many trees. It will take months of work to clean up and put back up the tubing.
>
> (Minnesota, Large)

Other comments describe actions taken by respondents to enhance their sugar bushes or the health of their maple trees. These actions include removing other species, planting sugar maples, removing invasives, and using small spigots. A few individuals report 'resting' trees in some years, either as part of a rotation scheme or in response to environmental stress such as drought.

> More selective in tapping trees to ensure only healthy trees are tapped and to rotate trees on and off from year to year
>
> (Minnesota, Small)

Adaptation Activities – Likelihood of Future Actions

Respondents were also asked to indicate their likelihood of undertaking the same eight adaptation activities in the next ten years. The question was asked on a 5-point Likert scale from 1 (very unlikely) to 5 (very likely). For analysis purposes, a binary variable was created if a respondent selected a value of 4 or 5 on the response scale, indicating they had some likelihood of undertaking the activity (1 = likely to undertake the activity, and 0 otherwise). Across all producer size classes, three of the adaptation activities are likely to be undertaken by at least half of the respondents: adopting different technology, increasing number of taps, and managing for healthier trees (Fig. 2). Slightly less than one-half of respondents indicate they plan to manage for more productive trees in the future. The activities least likely to be undertaken include: tapping non-sugar maples (7%), product simplification (4%), and planting climate change resilient maple trees (3%).

Chi-square tests were undertaken to examine whether the likelihood of implementation of adaptation activities varied by producer size class. For three of the activities, no statistically significant differences were found (planting climate change resilient maple trees, maple product simplification, tapping species other than sugar maple). For

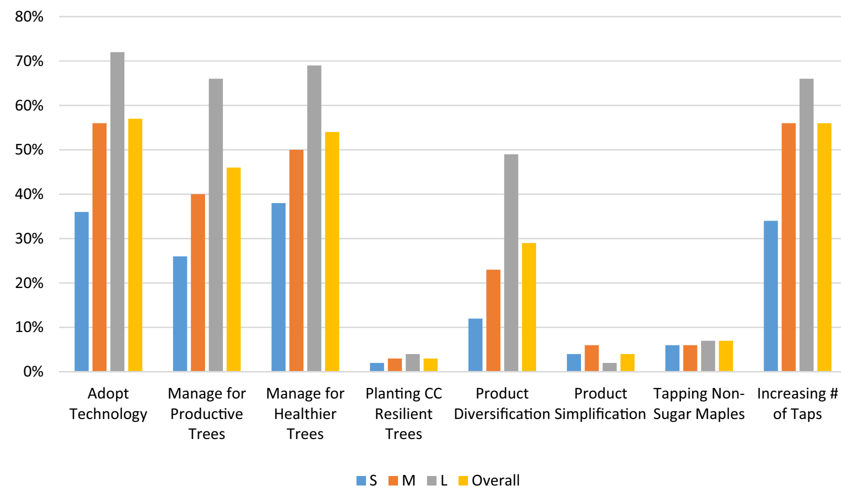

Fig. 2 Likelihood of undertaking adaptation activities in the next ten years by producer size class (percentage of respondents)

the other five activities, levels of implementation did statistically differ by producer size class: adopting different sugaring technology ($\chi^2(2,\ N = 257) = 17.0206,\ p = 0.0002$), active management for more productive trees ($\chi^2(2,\ N = 267) = 23.6470,\ p < 0.0001$), active management for healthier trees ($\chi^2(2,\ N = 257) = 13.1908,\ p = 0.0014$), product diversification ($\chi^2(2,\ N = 260) = 23.7684,\ p < 0.0001$), and increasing number of taps ($\chi^2(2,\ N = 293) = 13.6655,\ p = 0.0011$).

For S producers, the three activities they expressed the greatest likelihood of undertaking were managing for healthier trees (38%), adopting different sugaring technology and equipment (36%), and increasing the number of taps (34%). These same activities were also in the top three activities likely to be undertaken by M producers, but a greater percentage of M producers expressed interest in adopting different technology (56%), increasing the number of taps (56%), and managing for healthier trees (50%) than did S producers. Even higher percentages of L producers intend to undertake the same three activities than the other two producer size classes; e.g., 72% intend to adopt different technology, 69% intend to manage for healthier trees, and 66% intend to add more taps.

Comparing rates of past implementation to likelihood of future implementation of the same activities, all three producer size classes indicate increased interest in undertaking many of the adaptation activities. For example, 8% of S producers had managed for healthier trees in the past, whereas 38% intend to do so in the future. Thirty-nine percent of L producers had reported adopting different technology in the past, while 72% report an intention to do so in the next 10 years.

Concerns Related to the Future of Their Sugaring Operation

Respondents were provided a list of 13 factors related to the future of their sugaring operation, and asked to rate their level of concern for these factors on a 5-point Likert scale that ranged from 1 (No Concern) to 5 (Significant Concern). Average Likert-scale ratings were computed for each producer size class and over all respondents (Table 7). When examining responses over all producer size classes, six factors averaged three or higher on the concern scale, with tree health being the highest-rated factor (3.4). Sugaring profitability and threats related to weather conditions and variability registered less concern. Little concern was expressed about having adequate information and training on sugaring technologies and syruping workforce availability. Concern varied somewhat by producer size class for the 13 topics, but in general, average concern ratings increase as producer size increases for most of the concern topics.[1]

The top three concerns for S producers were: tree health (3.1), weather threats (2.9), and physical ability to continue sugaring (2.9). Medium producers' greatest concerns were different than S producers, with a focus on their physical ability to continue sugaring (3.6), stringency of sugaring regulations (3.4), and having family members interested in continuing the operation (3.3). Large producers were most concerned about sugaring profitability (4.0), pest threats (3.8), and tree health (3.8). Syruping workforce availability was the least concerning factor among S and M producers, while boil season-length registered the least concern among L producers. Only one topic averaged an average Likert-scale value of four among any of the producer size classes,

[1] Cumulative ordered logit models were run for each of the 13 potential factors of concern to test for statistical differences in ratings by the producer size classes (See Snyder et al. 2018). Statistically significant differences were found in concern ratings by producer size class for all factors except for 'threats from invasive plant species' and 'weather threats.' Considering both the average Likert scale values (Table 7) and the cumulative ordered logit results from Snyder et al. (2018), concern for factors affecting one's sugaring operation generally increase with producer size class. However, overall, respondents tended to rate most of the factors with only moderate levels of concern.

Table 7 Concern for factors related to the future of their sugaring operation by producer size class (Average Likert-scale Rating with 1 = No Concern and 5 = Significant Concern, standard deviation in parentheses)

Sugaring operation factor	Small	Medium	Large	Overall
Sap production per tap	2.58 (1.11)	2.92 (1.38)	3.22 (1.37)	2.94 (1.36)
Sugaring profitability	1.60 (0.98)	3.17 (1.47)	4.00 (1.29)	3.16 (1.56)
Boil season start and stop dates	2.21 (1.30)	2.81 (1.39)	2.60 (1.35)	2.62 (1.38)
Boil season length	2.33 (1.26)	2.89 (1.36)	2.10 (1.35)	2.71 (1.36)
Weather threats	2.92 (1.27)	2.91 (1.39)	3.09 (1.30)	2.96 (1.35)
Pest threats	2.79 (1.39)	3.00 (1.44)	3.84 (1.24)	3.28 (1.42)
Invasive plant species threats	2.75 (1.40)	2.73 (1.36)	3.25 (1.34)	2.90 (1.40)
Tree health	3.12 (1.31)	3.27 (1.26)	3.82 (1.06)	3.42 (1.26)
Syruping workforce availability	1.60 (0.93)	2.24 (1.34)	2.76 (1.35)	2.29 (1.32)
Physical ability to continue sugaring	2.89 (1.53)	3.55 (1.33)	3.14 (1.49)	3.26 (1.44)
Family members interested in continuing the operation	2.84 (1.63)	3.32 (1.38)	3.32 (1.26)	3.23 (1.47)
Sugaring rules and regulations	1.90 (1.29)	3.45 (1.45)	3.61 (1.31)	3.21 (1.49)
Information/training on sugaring technologies	1.89 (1.11)	2.75 (1.31)	2.86 (1.39)	2.61 (1.34)

and that was concern over sugaring profitability by L producers.

The qualitative data provide additional insights into factors that affect the future of some producers' operations. Personal obstacles to sugaring include the demands of other work and declining health and injury, the latter sometimes explicitly associated with aging. This suggests there may be a life cycle pattern in which the scale of small operations increases following sugarers' retirement from other work, followed by diminished production with advanced age and/or health challenges, at which point the survival of the operations in all producer size categories is in question where younger family members are not interested in taking over.

> We are concerned with keeping the family operation going. Our children are not close by. One is in Alaska and we would like to keep the operation family owned in the future.
> (Wisconsin, Large)

> Because of physical limitations (mainly arthritis) we could no longer continue.
> (Minnesota, Small)

Expectations for Their Operation

Respondents were asked how they expect their syrup production levels to change in the next ten years on a 5-point Likert scale ranging from a value of 1 (decrease greatly) to a 5 (increase greatly). Overall, the average Likert-scale score was 3.7, indicating expectations for increasing future levels of production (Table 8). The majority of respondents (85%) anticipate either stable or increasing levels of production.

Table 8 Expectations for syrup production levels in the next 10 years (percentages of respondents by producer size class)

Change to syrup production level	Small	Medium	Large	Overall
Decrease greatly	2%	2%	2%	2%
Decrease somewhat	10%	7%	7%	8%
Stay the same	43%	30%	13%	26%
Increase somewhat	31%	42%	49%	42%
Increase greatly	6%	14%	27%	17%
Don't know	8%	5%	2%	5%

Overall, only 10% of respondents anticipated a decline in production levels and only 8% were uncertain. Thus, respondents irrespective of producer size class were generally optimistic about the future of their operations and production levels.

Producers also were asked to indicate their level of agreement with a statement related to the future of their sugaring operation and their confidence in adapting to ecological conditions. Specifically, the statement posed was: "I can adapt to changing ecological and/or weather-related conditions in the next 10 years." Five-point Likert scale response options were offered and ranged from 1 (strongly disagree) to 5 (strongly agree), along with an N/A response option. Respondents were generally optimistic that they can adapt to future conditions. Specifically, almost half of respondents (48%) answered with a 4 or 5 in their ability to adapt to ecological conditions (Fig. 3). Only 10% answered with a 1 or 2. In addition, the average Likert-scale response for the ecological adaptation question was 3.6 over the three producer groups. Overall, these data suggest neutral to optimistic views on adaptation to future ecological and weather conditions. Cumulative ordered logit models were run to test for differences in ratings by the producer size classes, and no statically significant difference by producer size class were found.

Information and Assistance Needs

Respondents were asked to consider seven information/training topics and rate their importance on a scale of 1 (not important) to 5 (very important). Based on mean response ratings, the topic of greatest importance among all respondents was tree health, followed by information on improving profitability of one's sugaring operation (Table 9). Approximately two-thirds of all respondents rated the importance of information on increasing the health of their trees and information to improve marketability of maple products as four or greater. The only topic that rated an average score less than three was information associated with product diversification.

When viewed by producer size classes, average importance ratings increased as producer size class increased. Specifically, S producers had the lowest mean scores for all topics and L producers had the highest mean scores for all information topics. The highest-rated importance topic for S producers, and the only topic with a mean score greater than three, was tree health with a mean Likert rating of 3.6. Average importance scores were higher for M than S producers for all of the topics. As with S producers, tree health was the highest-rated information topic, followed by information on increasing profitability and learning about new processing methods. Large producers expressed the greatest interest in all of the information topics. Three of the topics were rated by L producers with an average importance score higher than four: information on profitability, marketing, and tree health.

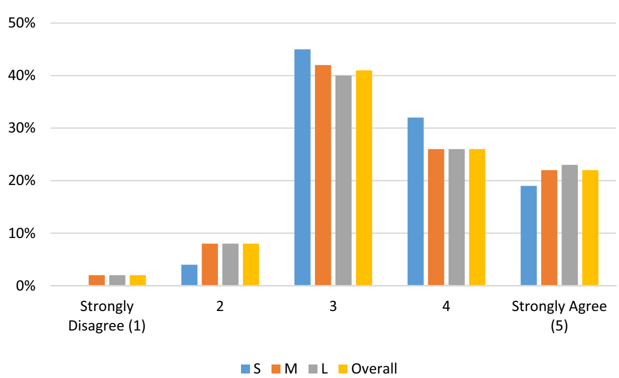

Fig. 3 Confidence in ability to adapt to ecological conditions in the next 10 years by producer size class (percentage of respondents)

Discussion

Equipment and Technology

The equipment used in sap collection and processing is a fundamental element of a syrup operation, and one that is being used by some as both a means to increase output and efficiency and to circumvent or moderate weather and climate conditions. While many respondents indicated that their method of adapting to earlier or more variable sap flows was simply being prepared to tap earlier, utilization of different technology was also reported by respondents as an adaptation mechanism. For example, when tubing is used instead of sap buckets, there is lower likelihood that parts of the sap run may be missed. In addition, use of tubing with vacuum can extract more sap from trees than if gravity tubing or sap buckets are used (van den Berg et al. 2016). Thus, when compared to more traditional sap collection methods, the use of more advanced technologies will typically increase output and efficiency, which may give producers an elevated perception and confidence that weather and climate vagaries can be overcome through technology. Our findings about the reliance on technology as a response strategy to climate impacts confirms what other studies of maple syrup producers have found. For example, of those producers in the Murphy et al. (2012) study who indicated that climate change had or would impact their operations, utilization of new technology was the action the highest percentage of respondents (57%) mentioned as an action they would take to deal with climate impacts. Similarly, adoption of new technology was also the most commonly mentioned activity that New York and Vermont syrup

Table 9 Importance of information/training topics by producer size class (average likert-scale rating with 1 = Not Important and 5 = Very Important, standard deviation in parentheses)

Information topic	Small	Medium	Large	Overall
Increasing production	2.31 (1.10)	3.27 (1.40)	3.85 (1.26)	3.30 (1.39)
Tree health	3.61 (1.02)	3.75 (1.06)	4.12 (1.00)	3.87 (1.04)
Collection and processing methods	2.78 (1.30)	3.46 (1.26)	3.79 (1.21)	3.45 (1.28)
Marketing	1.98 (1.33)	3.28 (1.36)	4.13 (1.18)	3.40 (1.46)
Profitability	2.08 (1.31)	3.52 (1.40)	4.31 (1.07)	3.63 (1.45)
Product diversification	1.98 (1.35)	2.62 (1.49)	3.49 (1.38)	2.88 (1.54)
Succession planning for syrup operation and/or sugar bush	2.29 (1.56)	3.06 (1.48)	3.40 (1.57)	3.07 (1.54)

producers (26%) have or are planning to take in response to climate change (Kuehn et al. 2016).

Given that technology seems to offer producers confidence in their ability to face weather-related challenges, this may explain why respondents report being generally optimistic about the future of their operations and express little concern about climate impacts. An issue, then, is that while technology does allow producers to adapt to variability in timing and continuity of sap flows, these technologies do not address associated impacts to sugar bush health (e.g., increased vulnerability to disease, pests, and extreme weather events). Thus, if producers feel equipped and able to respond to sap season and flow variability through changes in technology, they may be less motivated to acknowledge or take actions to address other stressors associated with weather and climate variability. This reliance on technology as a climate adaptation strategy has also been documented within the context of farming systems and agriculture (e.g., Smithers and Blay-Palmer 2001).

Further, as was noted by some respondents in open-ended responses, cost-share assistance is not available to producers in the region to make the purchase of equipment more feasible. So, if a producer is not able or interested in purchasing and utilizing these advanced technologies, their operations may be less resilient to change over time. Equipment costs may represent a barrier for some producers to expand production and/or increase efficiency of their operations, as well as a potential barrier for new producers to develop an operation. Results from the Murphy et al. (2012) study support this contention in that approximately one-third of respondents agreed that expenses represent a barrier to climate adaptation approaches for their syrup operations.

Adaptation Activities Already Undertaken

In general respondents, regardless of producer size class, have not perceived trends in a variety of factors related to sap season conditions over the past 10 years. The one exception appears to be some agreement among respondents in our study and others (Murphy et al. 2012, Kuehn et al. 2016) that there is a trend towards earlier start date of the sap season. While many respondents indicated they have experienced *variability* in factors such as timing and continuity of sap flow in open-ended responses, they are not seeing strong, consistent trends. Murphy et al. (2012) reported that the majority of the producers in their study perceived no change in variability in a number of weather and climate-related factors (e.g., incidents of drought, severity of storms, wind, rain, number of storms), while they did perceive greater variability in several other factors (night temperature, daytime temperature, snow cover, sap production). The perceived lack of trends in sap season factors in our study may, in part, explain why so few of our respondents indicated undertaking actions specifically out of concern for climate issues. In the absence of clear trends, it is hard for producers to develop an effective or consistent approach to adapting to weather and climate-related factors. When queried about activities that could be viewed as adaptation strategies to various stressors, the activity that both M and L producers are most likely to have already done is adopt different technology or equipment for extracting or processing sap. In the case of commercial producers, the adoption of new technologies could be viewed either as a means to moderate uncertainty in sap season conditions and/or a progression of adoption of more sophisticated equipment to expand the scale and profitability of operations, and as an ancillary benefit may provide buffering against sap season variability. None of the producer size classes have done much in the way of planting climate resilient maple cultivars. Reasons for low levels of implementation for this activity could be lack of availability, knowledge, or interest and/or associated costs, as well as the long payback time of planting a tree and waiting for it to grow to a tappable size.

In general, S producers have not undertaken any of the queried adaptation activities to any great degree. Managing for healthier trees was the activity with the highest percentage of S producer participation, but that was only 8% of S respondents. Thus, these individuals, many of whom are likely hobby-scale producers, may not view the queried activities as relevant or affordable for the scale of their operations. Small producers may also not be interested in making large or long-term investments in their operations through the purchase of new equipment. For these small-scale producers, management of their sugar bush for more productive and/or healthier trees may be a topic of greater resonance.

While many respondents in our study indicated they have undertaken or plan to undertake activities that could be viewed as adaptation activities, only 11% had done so or were planning to do so out of specific concern over climate conditions. The lack of action out of concerns about climate-related impacts could be attributed to myriad factors. One reason, as noted by some of the respondents, is that weather and sap season variability have always been part of the syrup production. Thus, either significant enough changes or trends have not been observed to necessitate changes and/or changes that have been observed aren't viewed as attributable to long-term climate changes. Compared to other studies of maple syrup producers, respondents in our study appear less likely to undertake actions out of specific concern for climate conditions. For example, 58% of respondents in Kuehn et al. (2016, 2017) indicated at least one concern related to climate change and their sugaring operation, and 66% indicated they had or were planning to make changes to their operations out of specific concern for climate change. Similarly, 70% of respondents in the Murphy et al. (2012) study indicated climate change has or will impact their business, and of these respondents, 57% plan to adopt new technology and 48% to undertake active tree management in response to climate change concerns. However, as noted by Murphy et al. (2012), these two activities are simply a part of 'normal sugarbush management' and thus may not truly reflect purposeful adaptation efforts to climate conditions. While it could be possible there are national or regional differences in attitudes and perceptions towards climate change and its potential impacts to sugaring operations, differences in findings between the three studies could also potentially be attributed to differences in question format and study methods, different climate trends in the Lake States relative to other parts of North America, as well as differences in size of sugaring operations, years of experience with sugaring, or percent contribution of sugaring profits to household income. Further research is needed to explore these and other questions related to potential differences in attitudes, behaviors, and intentions related to climate change and sugaring operations among different producer groups.

Given that Mathews and Iverson (2017) and the Landscape Change Research Group (2014) report that future climate conditions are likely to adversely impact sugar bush health and productivity through droughts and increased insect infestations in the coming century, this lack of concern and action on the part of maple syrup producers in the Lake States may be cause for concern. One implication of producers' attitudes and actions towards climate change is that messaging, outreach and management strategies specifically invoking climate change or variability isn't likely to be an effective way to motivate syrup producers in the Lake States, at least at the present time. Messaging and management strategies more centrally focused on the impacts to the health and productivity of sugar bush and how to address them might resonate more.

Future Adaptation Activities

When considering the activities that respondents indicated they were likely to undertake in the next 10 years, we find much higher percentages of respondents expressing an intent than had done so in the past. These findings could signal a growth period in the industry in the region. It could also reflect a progression of increased investment as smaller producers move to expand operations; the 'hobby out of control' sentiment that was mentioned in some open-ended comments. It could be a desire to increase efficiency of operations that often comes with the availability of advanced technologies and rising production costs. Finally, the interest in adopting technology and active management of the sugar bush could be a reaction to ecological conditions and challenges such as pest, disease or weather event issues that may be forcing producers to more actively consider activities such as enhanced sugar bush management. Our qualitative data offer evidence of lifecycles for sugaring operations that parallel respondents' lifecycles, suggesting caution, however, in portraying enhanced future interest in sugaring activities as an inevitable, unidirectional process.

As with the question that focused on activities completed in the past, none of the producer size groups indicated they are likely to plant climate resilient maple cultivars, tap non-sugar maples (e.g., boxelder, birch, silver maple), or engage in product simplification (e.g., reducing the number of maple products produced). Thus, significant assistance and outreach might be needed for these activities to gain traction with Lake States producers. While few of the respondents in our study expressed experience or interest in experimenting with other trees, possibilities may exist or become more attractive in the future for development of fledgling industries from other tree species. Farrell (2009) suggests potential for enhanced reliance on red maples (Acer rubrum) in syruping operations, which may not suffer the same declines in abundance in eastern forests as sugar maples. Two respondent's survey comments indicate they already are tapping red maples.

Respondents expressed confidence in their ability to adapt to changing ecological conditions. While respondents weren't specifically asked what influenced their response, a number of factors are likely at play. Respondents could feel that conditions aren't changing or changing enough to warrant adaptation approaches to their operations. Alternatively, they may agree that conditions are or could change, but feel that they possess the requisite knowledge, tools, skills, capital, and resources to overcome conditions. Regardless of the reasons underlying responses to this question, the belief that they can readily adapt to conditions could be a barrier to adoption of new strategies that may eventually be required by changing conditions. Our results that producers are generally optimistic about their future and ability to adapt are consistent with those of Murphy et al. (2012) who found that 58% of their respondents strongly or very strongly agreed that they can adapt their sugaring operations to climate change in the next year years. However, our results contrast somewhat with those of Kuehn et al. (2017) in which producers in their study, on average, did not perceive at the present time that their business would be able to easily adapt to future climate change.

An activity that many respondents do intend to undertake in the next 10 years is tap expansion, as was also found by Kuehn et al. (2016). Approximately 65% of L producers and 55% of all of our respondents anticipate increasing the number of taps used in the next 10 years. Thus, there is a desire for production expansion, which appears realistic for the Lake States. Mathews and Iverson (2017) suggest significant opportunity for increasing the number of taps for sap extraction throughout the range of the sugar maple, with Michigan having particular capacity to do so. However, it will be important that producers follow best management practices regarding tapping guidelines. Installing too many taps in a given tree, or tapping trees that are too young or those impacted by drought, diseases or pests will serve to further stress a sugar bush and not result in gains to production (Houston et al. 1990). van den Berg et al. (2016) note that sap removal practices associated with vacuum tubing and other modernizations can remove double the amount of sap from more traditional removal methods, and that care must be exercised in ensuring one's tapping and extraction system are sustainable for the conditions of the sugar bush.

Concerns and Needs

While respondents expressed moderate levels of concern about factors associated with the future of their sugaring operation, higher average concern ratings were expressed for factors such as profitability and the impacts of rules and regulations than sap season variability and weather threats, particularly among M and L producers. One implication of this concern about profitability, particularly among L producers, is that they may be reluctant to embrace any adaptation, sugar bush management, and/or production strategy that is seen as negatively impacting profitability. Tree health was the highest-rated concern and desired information topic. This suggests an opportunity and a need for extension and consulting foresters to develop education and outreach materials, training, messaging that specifically targets stewardship and management efforts to enhance sugar bush health and productivity. Given limited concern about climate change issues, outreach and messaging to enhance tree health will likely be more effective if it isn't tied to messaging related to climate change.

The majority of respondents indicated expectations for stable to increasing levels of production over the next 10 years. While this is an optimistic sign for the industry in the Lake States, one must wonder if this expectation is more aspirational than realistic. Specifically, the average age of respondents was 60 and respondents indicated concern over their future physical ability to continue their operations and the potential for continued family involvement. Moreover, respondents also indicated a lack of financing and cost-share assistance available to them which might allow them to upgrade their equipment and production facilities. Thus, while this expectation of increased production is a positive indicator, it should be tracked to determine whether increasing production is indeed possible and occurring among producers in the region, as well as whether new operations are being established in the Lake States.

Conclusions

Like many other non-timber forest products, the production of maple syrup is directly tied to weather and climate conditions. However, few producers in our study expressed specific concern about how climate variability has or may impact their syrup operations. Moreover, only a small percentage of our respondents report having taken actions specifically out of concern for or in response to climate change. Utilizing new sap collection and processing equipment and altering their syrup production schedule have largely been viewed as adequate strategies to circumvent any *direct* impacts that may be stemming from climate variability; e.g., changes in sap season timing. However, other impacts that may be associated with climate stressors, such as threats to sugar bush health from drought, pests, invasives, and disease, will call for additional management or adaptation strategies, regardless of whether producers view these actions are motivated by or associated with climate conditions.

It is clear that sugar bush health is a topic of considerable interest and concern to producers in the Lake States. Among all producer size groups, tree health was both the highest-rated information need and factor of concern impacting the future of one's operations. Moreover, more than half of all respondents intend to actively manage their sugar bush in the future for healthier trees. These facts underscore needs and opportunities for Extension agents, service foresters, and MSPAs to promote forest management practices that not only contribute to productivity and longevity of sugaring operations, but can also contribute to overall forest health. It is important to emphasize, though, that producers do not appear to be linking this concern about forest health with climate stressors. Given this, climate variability may not be the right messaging frame to use at this time when talking with producers about strategies for enhancing sugar bush health. This interest by producers in information and assistance related to tree health might also represent an opportunity for enhanced interactions with professional foresters and other services they can provide. For example, research suggests that sugar bush management can be practiced in ways that emphasize ecological benefits like biodiversity conservation and habitat protection (Clark and McLeman 2012). However, in a study in Ontario, Clark and McLeman (2012) found that few sugar bush operators had a forest management plan with specified forest management goals for sugar bush health, let alone biodiversity or conservation practices.

A theme among some respondents in open-ended comments, notably L ones, was the impact of regulations and competition with Canadian producers. The Canadian government provides support for maple syrup production through cost-sharing programs for equipment purchase and attractive lease rates on public lands for tapping (Farrell 2009). Respondents in our study lamented the lack of similar government assistance for operations in the U.S. Producers in our study are keenly aware of the competitive advantage that Canadian producers enjoy, and point to this as a constraining factor in growing their operations in the Lake States.

We segmented our data by producer size classes to explore whether differences in attitudes and behaviors exist as a function of the number of taps set for typical producer sizes in the Lake States region. Our data illustrate that differences do exist for some factors and behaviors such as perceptions about sap season conditions and trends, adaptation activities, likelihood of future adaptation activities, and information needs. The implication of these findings is that for others who do future research on maple syrup producers, parsing by levels of production (or other metrics meaningful to the study population and locale) may allow for more nuanced understanding. As well, these findings also indicate that outreach programming to maple syrup operators should consider how needs and concerns may differ as a result of production size.

There are many indications in our results that producers in the Lake States are optimistic about the future of their operations and planning to undertake activities that could serve to expand their operations, from increasing the number of taps they plan to set to management for a healthier sugar bush. While sugar maple habitat suitability projections suggest that the maple resource in the Lake States may be stable to increasing in the future under different climate models (Mathews and Iverson 2017), that is not to say that maple syrup producers in this region will be immune to stressors associated with climate and weather variability, market forces and sugar bush health. Thus, the optimism expressed by our respondents may at some point need to be tempered by the reality that more active planning, management and adaptation to ecological, weather and market-related factors may be needed in the future. For the time being, producers in the Lake States feel like they have largely been able to adapt to variability in sap season conditions by being prepared to tap trees earlier and through adoption of new sap collection and processing equipment. If future climate scenarios play out, then additional planning and adaptation strategies may be called for, particularly as they relate to forest health and productivity issues.

Data Limitations and Future Research Needs

It is important to underscore that our analysis focused on producers who belonged to a maple syrup producer association at the time of our survey. Given this, they probably are a more engaged, motivated group of syrup producers than those who are not members. Moreover, our research does not lend insight into what barriers or information needs might exist for sugar bush owners who aren't currently engaged in tapping and/or syrup production, but might have the potential to do so. Additional research is needed to increase our understanding of the types of information, outreach, assistance, and mentoring that might be needed to facilitate the entry of new syrup producers in the Lake States. Our research into maple syrup producers is situated in a much broader literature associated with attitudes, behaviors, and adaptive capacity of agricultural producers in general and non-timber forest product (NTFP) producers and gathers more specifically. More research into how the attitudes and behaviors of maple syrup producers may compare to these other two groups regarding their adaptive capacity could lend insight into whether maple syrup producers have any unique behaviors or insights.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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