AN ALTERNATIVE MEASURE OF YEARLY MAPLE SYRUP PRODUCTION (YIELD-PER-TAP/DAY)

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INTRODUCTION

The success of the sugar maple industry is strongly associated with minor meteorological variations that affect sap production (MacIver *et al*., 2006). Maple syrup production is one of the most poorly forecasted crops in the U.S. (Morrow, 1973), because sap flow is dependent upon critical changes in temperatures during a relatively short period of alternately freezing and thawing diurnal temperatures. Maple sap is collected for approximately 4-6 weeks each year under specific weather conditions that occur in northeastern North America from February-April. Optimal climatic conditions include a combination of nighttime temperature minima (< 0°C), contrasting warm, sunny days (> 4°C) (Marvin, 1957, 1958), and sub-freezing soil temperatures that delay the onset of budding.

Typically, production is measured in terms of the number of gallons produced. Where, bumper years are identified by years of above-average production preceded by a series of below-average years. Production, as measured by the number of gallons produced does not offer much information about the efficiency of sap flow for a given year or region. The number of gallons produced during a season can be influenced by the physical environment (e.g., meteorological) and variables such as the number of producers and trees tapped, and season start and end dates. To adjust for these factors and to provide a measure that would express the meteorological-based variation in yield, the industry standard, Yield-per-Tap, is commonly used. Thus, this measure allows practical comparisons between years and regions where syrup is produced.

Despite improved collection techniques and changes in sugarbush management strategies to enhance sap collection during suboptimal periods throughout the twentieth century, between 1967 and 2008, average maple syrup production (Yield-per-Tap) has declined by 22 percent in New York (Fig. 1). A suite of causes have been identified for the decline including forest pests and diseases, nitrogen leaching, elevated carbon dioxide, ice storms, summer and fall droughts, decreased snow cover, and increased springtime temperatures. As changes in weather conditions during the sugaring season continue to reduce sap flow (Skinner *et al*., 2009), considerable attention has been placed into further understanding and quantifying the current state of decline. Therefore, an adjusted measure of production may enhance the understanding of yield behaviors of the last 42 years.

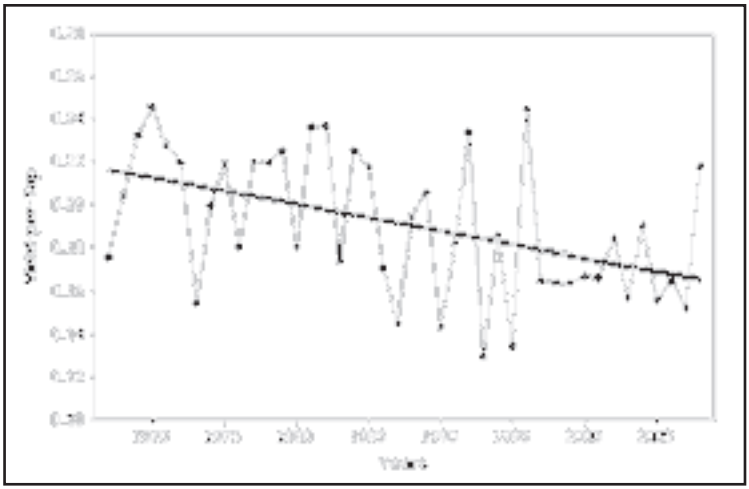

Figure 1. Yield-per-Tap for the period 1967-2008; (R^2 = 0.21, p = 0.002, D-W = 2.3).

Increases in springtime temperatures (e.g., minima and maxima) not only affect sap flow but dictate start and end dates (i.e., season length) of the sugaring season. The effect of a shorter sugaring season on syrup production has been implicated as a factor contributing to the decline over the last two decades. Season length, however, does not take into consideration the number of ideal days within that season. Additionally, as increases in springtime temperatures for the northeastern United States are forecasted to continue, the relationship between season length and production requires further investigation.

While the adjustments for non-meteorological effects provide a robust measure of yield behavior, the influence of season length still remains. Therefore, in order to evaluate the effects of season length of maple syrup production I purpose an alternative measure of seasonal maple syrup production, "Yield-per-Tap/Day." I then determine whether the addition of season length affects the calculated rate of decline in production during 1967-2008. Lastly, after ranking the years of production, the bottom and top 10 years are compared for the two measures of production.

MATERIAL AND METHODS

Statewide yearly maple syrup production (gallons), number of taps, and Yield-per-Tap values were obtained from the United States Department of Agriculture's National Agricultural Statistics Service New York Field Station for 1967-2008. Additionally, I obtained yearly sugaring season start and ends dates to calculate a season length using the Julian dates (e.g., January 1st = day 1) and tested the 42-year period (1967-2008) for change in season length using simple linear regression.

Next, I calculated a new index (Yield-per-Tap/Day) by dividing the Yield-per-Tap for a given year by the sugaring season length for that year. Dividing Yield-per-Tap

by season length will produce a new data series that takes into consideration seasons with more days of potential sap flow, thereby, rescaling production.

Simple linear regression was then used to determine if there was a statistical relationship between season length and Yield-per-Tap and whether a significant decline in both Yield-per-Tap and Yield-per-Tap/Day for the period of 1967-2008 was present. Additionally, the Durbin-Watson statistic (D-W) was calculated to check for autocorrelation in the time series. I then determined if the slopes (i.e., the rate of decline) for the two models were statistically different. Lastly, I ranked the two data sets and analyzed the top 10 and bottom 10 years of production to see if temporal patterns of production change after correcting for season length.

RESULTS AND DISCUSSION

While it has been reported that the sugaring season is starting earlier and season length has decreased by three days in some regions of New England (O'Connor, 2007), no significant change ($p = 0.450$) in season length was found for New York (Fig. 2). Conversely, a significant linear relationship between season length and Yield-per-Tap ($R^2 = 0.14$, $p = 0.007$) was found (Fig. 3), indicating that accounting for season length in yield measures may be appropriate.

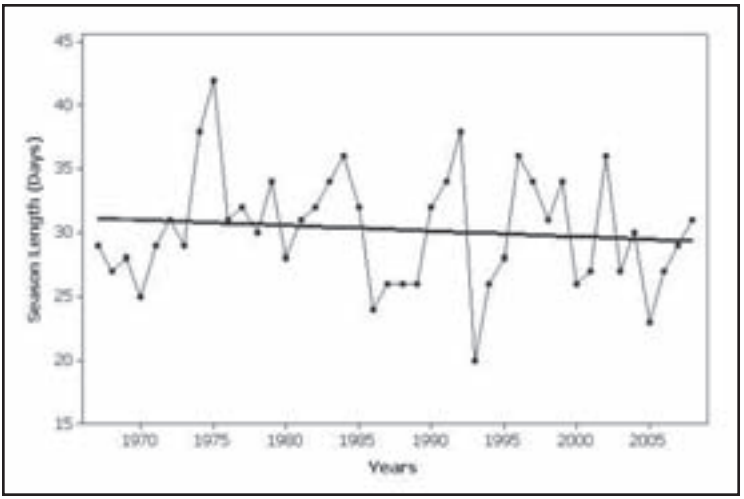

Figure 2. Length (number of days) of sugaring seasons for the period 1967-2008; ($R^2 = 0.02$, $p = 0.45$, D-W = 1.52).

After removing the effect of sugaring season length on syrup production, average syrup production (Yield-per-Tap/Day) during the 1967-2008 declined 18 percent as compared to the 22 percent (Fig. 4) found when Yield-per-Tap is used. While it is not significantly different ($p = 0.668$), the difference in decline between the two models was 16 percent. Regardless, the addition of including season length may provide the industry and producers a more appropriate measure of decline, production, and identification of bumper years.

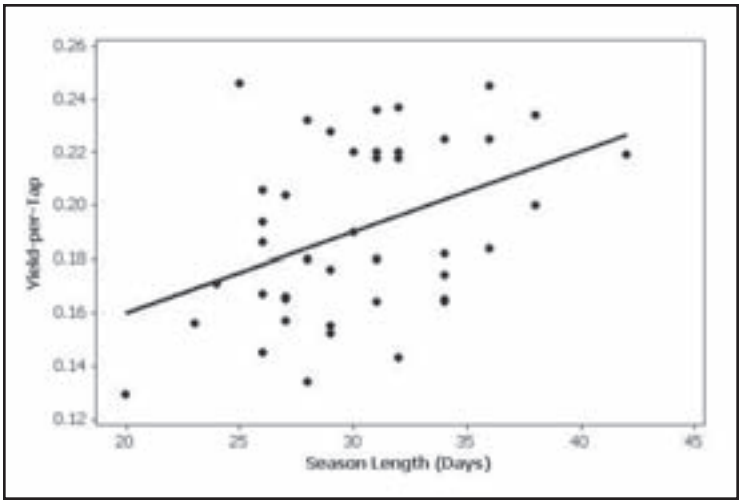

Figure 3. Yield-per-Tap as a function of the sugaring season length (1967-2008); (R^2 = 0.14, p = 0.001).

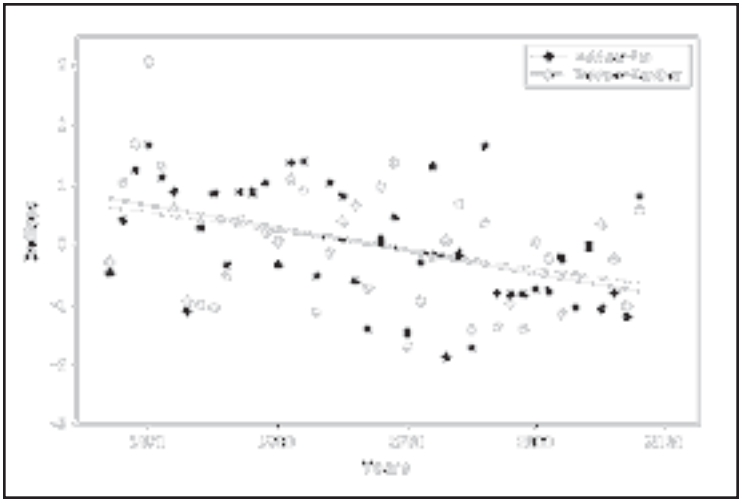

Figure 4. Standardized Yield-per-Tap and Yield-per-Tap/Day values for 1967-2008 with their respective trend lines. Trend lines are significant for Yield-per-Tap and Yield-per-Tap/Day (dashed line); R^2 = 19.0, p = 0.004, D-W = 2.3; R^2 = 13.0, p = 0.024, D-W = 1.42, respectively.

While both measure of production provide similar rates of decline and model fit (R2), the rankings of the top and bottom 10 years of production are not consistent (Table 1). Sixty percent (6/10) of the top 10 years and 40 percent (4/10) of the bottom 10 years are found within both measures (Table 1). However, only two (i.e., 1970 and 1995) of 10 common years hold identical rankings.

Table 1. The ranks (1 = highest, 42 = lowest) of yearly syrup production based on the two measures for 1967-2008. An asterisk (*) indicates common years found between measures (i.e., the year 1998 is ranked in the lowest 10 years of production regardless of which measurement is used). Bold values hold equal ranks.

Yield-per-Tap		Yield-per-Tap/Day	
Bottom 10 years of production			
Rank	**Year**	**Rank**	**Year**
33.5	1998	33	1991
33.5	1999	34	1974
35	2007	35	1975
36	2003	36	1983
37	2005	37	2002
38	1973	38	1997
39	1987	39.5	1998*
40	1990	39.5	1999*
41	**1995**	41	**1995***
42	1993	42	1990*
Top 10 years of production			
1	**1970**	1	**1970***
2	1996	2	1969*
3	1982	3	1989
4	1981	4	1971*
5	1992	5	1981*
6	1969	6	1968
7	1971	7	1988
8	2008	8	1982*
9.5	1979	9	1978
9.5	1984	10	2008*

CONCLUSIONS

For the state of New York, season length and Yield-per-Tap were positively associated. Conversely, no significant change was found for season length. Analysis of Yield-per-Tap and Yield-per-Tap/Day using linear regression does not reveal any statistically different results in terms of production trends. While statistically not significant, correcting for season length may highlight years with ideal conditions for syrup production despite average- to below-average yields. For example, if year 1 and 2 have the same yield, but year 1 had a 20 percent shorter sugaring season, then year 1 would be a more productive season. The ranked data however, suggests that inclusion of season length may help in iden-

tifying alternative bumper years. Because the data are derived from statewide surveys, these results and interpretations may not represent regional or local-scale maple syrup production. A regional average or a statewide regionally-weighted average may be more appropriate given the climatic and topographic variability of New York.

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