# Ecological Management for Sustained Maple Forest Health and Productivity

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- **Increased forest tree species biodiversity in sugar maple-dominated northern hardwood stands significantly reduces presence and impact of sugar maple insect and disease pests.**
- **Most maple sugarmakers are willing to change traditional sugarbush management techniques in order to gain increased pest resistance in their forests.**
- **Although stored carbon was significantly associated with basal area, there was no relationship with increased stand biodiversity in our study.**

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http://www.nsrcforest.org

# Project Summary

- In Vermont 31% of hardwood trees are sugar maple. In 2011, revenue from maple syrup sales in Vermont was $40 million. When revenue from value-added products such as maple candy and syrup repackaging was included it was $226 million. In New England maple is an important source of income for small family farms. A well-managed sugarbush represents a unique ecosystem providing valuable products and a verdant habitat with benefits including forest biodiversity and carbon sequestration. In Vermont >75,000 acres are managed for syrup production and in New England >130,000 acres. Historically, sugarbushes were pure monocultures of sugar maples with large, full crowns. These sugarbushes produced sweeter sap per tree, but were more vulnerable to pests and diseases negatively impacting tree health and sustainability. We compared the abundance and negative impacts of insect and disease pests between *Traditional management* where stands were 90-100% sugar maple, and *Ecological management* where about 25% of the basal area was non-sugar maple.
- Nine sites were chosen, three each in USDA plant coldhardiness zones 3, 4 and 5 in NY, VT, NH. At each site two operational sugarbushes were identified within 20 km of each other, one using the *Traditional management* approach, and the other *Ecological management*. At each sugarbush, four plot centers were established 100-200 m apart. At each center ten sugar maples were selected for pest assessments. Stands were visited three times per year to quantify pear thrips, maple leafcutter, sugar maple borer, maple trumpet skeletonizer, maple anthracnose, and eutypella canker populations. Stand health was estimated based on crown transparency ratings. Sugarmakers were surveyed for attitudes towards non-traditional sugarbush management. Carbon sequestration was determined at each plot with the *USDA FS Carbon Tools Model*.
- Highly significant differences in pest and disease incidence between the two treatments were found. Less defoliation, fewer insect pests, and less incidence of disease occurred in stands managed using the ecological approach. Differences were similar across cold hardiness zones and sites, but not always by year. This is due to normal yearly fluctuations in insect populations. The survey indicated that sugarmakers favored the new management style if their trees were healthier and lived longer. Carbon storage was not different between treatments. Basal area was a highly significant co-variate in the carbon analysis. By leaving a more biologically diverse forest, pest damage to maple is reduced, benefits to other wildlife species are enhanced, and the forest may be more resistant to climate change in the future.

# Background and Justification

Throughout the Northeast, the current economic boom in the maple sugar industry is driving the conversion of thousands of acres of multiple-use forestland to that with one purpose, maple sugar production. To many, this means heavily thinning the stand to leave only sugar maples. Early research papers, maple producer manuals and even some recent publications promote this type of management as large-crowned widely-spaced maples will produce more and sweeter sap (Moore et al. 1951, Foulds et al. 1956, Smith & Gibbs 1970, Lancaster et al. 1974, Walters 1982, Heiligmann et al. 1996). These traditionally managed sugarbushes are monocultures of co-dominant and dominant sugar maple trees. In other forested systems there is a relationship between monocultures and incidence of injurious insects and diseases (Belyea 1923, Taylor et al. 1996, Su et al. 1996, Needham et al. 1999). Monocultures of sugar maples could result in significant tree damage from pests and negatively impact long-term maple forest health, thereby neutralizing the reported advantages of this management strategy. It has been suggested that sugar maple monocultures typical of traditionally managed stands could promote rapid development of insect defoliators and increase susceptibility of the trees to vascular wilt diseases (Houston et al. 1990). Research has shown that damage by pear thrips and forest tent caterpillar reduces tree health, sap flow and sugar content for >2 yrs after infestation (Kolb et al. 1991, 1992; Gross 1991). Thus, traditional management techniques, though convenient operationally, may not promote sustainable forest productivity.

A healthy sugarbush with 25% of the basal area comprised of non-sugar maples.   Note slightly higher stem densities.

A sugarbush with 100% of the basal area in sugar maple.  Note the multiple large eutypella cankers and sugar maple borer wounds.

# Methods

## Plot set-up:

Three geographically similar areas were selected in each of three USDA plant coldhardiness zones (3, 4 and 5) acros NY, VT, and NH (Fig. 1). Within each area, two operational sugarbushes were identified as test sites: one comprising 90-100% sugar maple (*Traditional sugarbush management* (T)), and the other managed for 25% non-sugar maple species (*Ecological management* (E)). Selected stands were composed of pole to saw timber-sized trees suitable for tapping. Stands within a geographical area were located within 20 km of each other, but no closer than 2 km. Sites with favorable soil and drainage conditions for sugar maple were used to minimize indirect environmental effects such as extremely wet or dry soils. Within each sugarbush, four plot centers were randomly established 100-200 m apart. At each plot center ten nearby dominant sugar maples were randomly selected for pest assessments (Fig. 2). A total of 720 trees (360/management method) were sampled. A subset of 5 trees per plot center (n=360 total) were used for selected pest assessments. Stand data was collected at each plot center and entered into the Northeast Decision Model (NED-2) to determine stand parameters such as species composition, basal area, trees/ha, mean stand diameter, etc. (Twery et al. 2005).

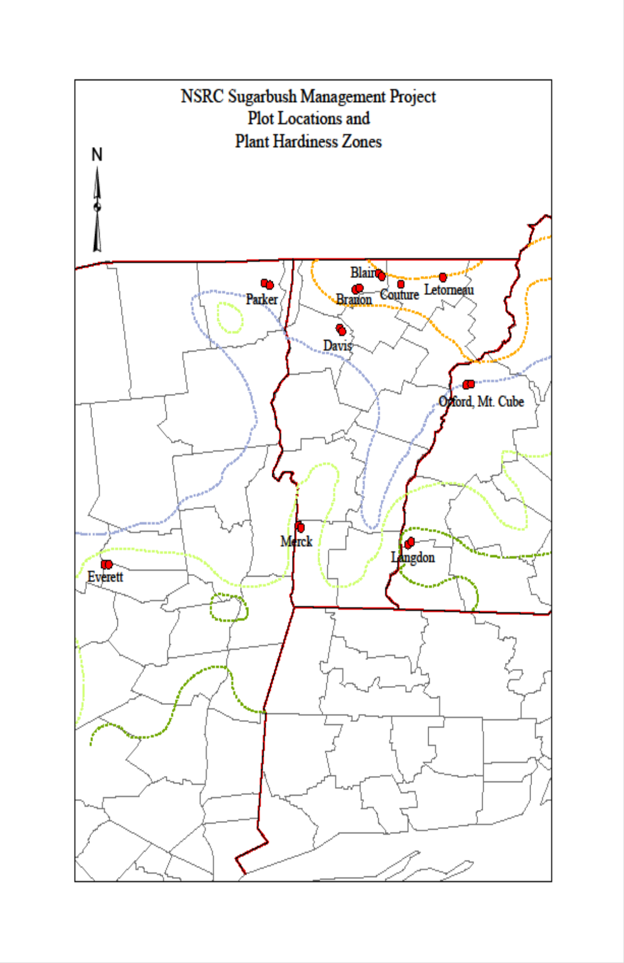



**Fig. 1. Map of plot locations**

# Plot layout.

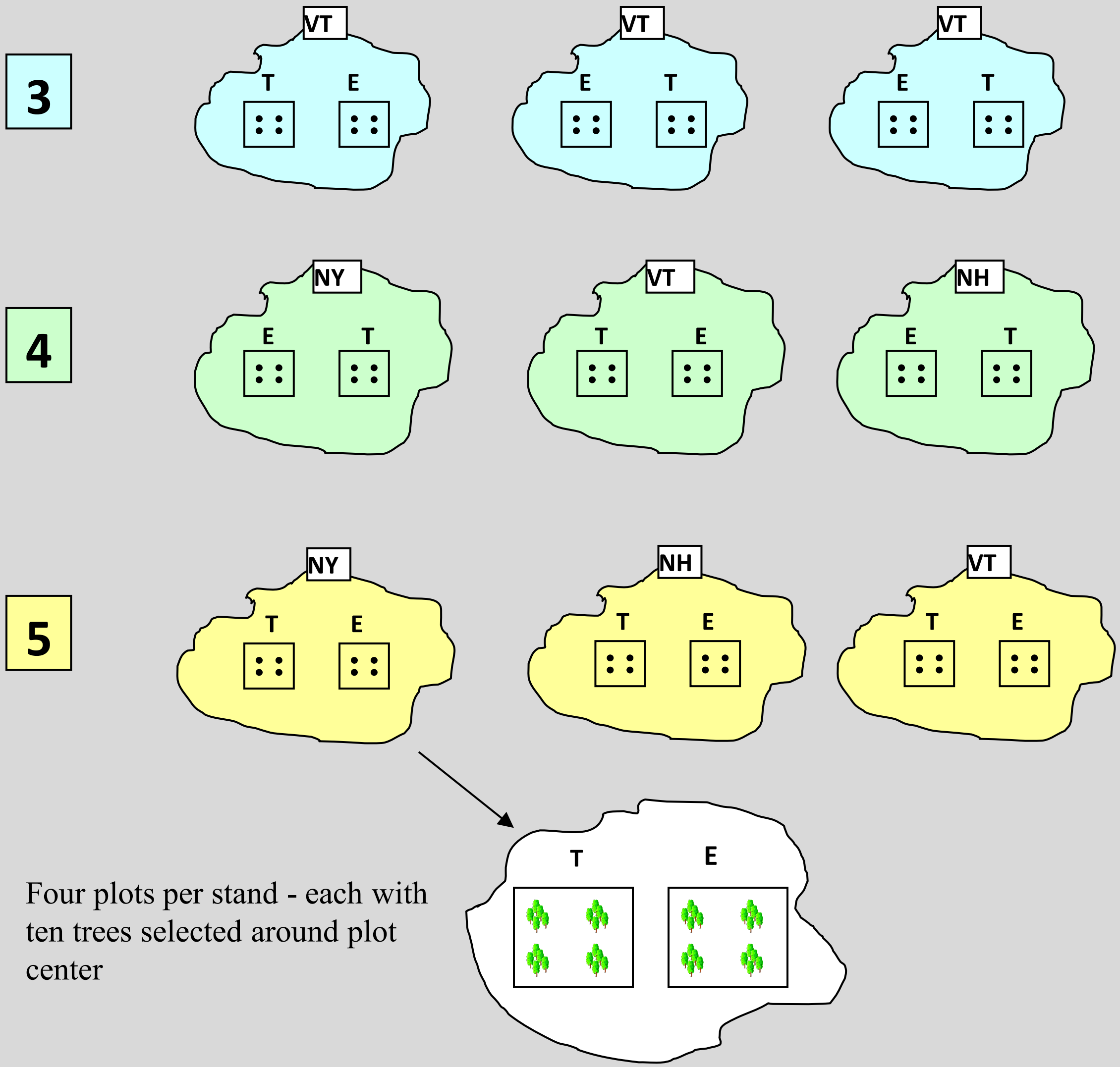



**Fig. 2. Plot layout: T =** Traditional sugarbush management (90-100% maple); **E** = Ecological ($\leq$75% maple)
● = Plot center.

**Data collection:** Each stand was visited three times per year to collect data, following standard recommended sampling practices (Table 1). Sample trees were assessed for the following pests/diseases (see descriptions below): pear thrips, maple leafcutter, sugar maple borer, maple trumpet skeletonizer, maple anthracnose, and eutypella canker. Overall stand health will be estimated based on crown transparency.

| | **Sampling Time and Method** | | |
|---|---|---|---|
| | **I. May/June** | **II. August/September** | **III. October** |
| Sugar maple borer | Visual inspection/count | | |
| Eutapella canker | Visual inspection/count | | |
| Pear thrips | Foliar damage assessment | | Soil core sampling |
| Maple trumpet skeletonizer | | Visual inspection/count | |
| Maple anthracnose | | Foliar damage assessment | |
| Maple leafcutter | | Foliar damage assessment | Leaf litter |
| Crown transparency | | Visual ranking | |

**Eutypella canker and sugar maple borer.** A stem analysis was done on each of the ten trees per plot and counts made of eutypella infections and SMB wounding from the base of the tree up to where the major branches fork out.

**Pear thrips.** At each plot center we sampled from 5 of the 10 trees (4 plot centers; 20 trees/sugarbush). At each tree one soil sample was taken at 2 m from the bole and processed for induced emergence of adults according to the protocol of Skinner and Parker (1995).

**Foliar damage assessments** for **pear thrips**, **maple anthracnose**, **maple leafcutter**, and **crown transparency** was done using NAMP protocol (Cooke et al. 1996) by NAMP certified personnel (D. Tobi & M. Skinner)**.**

**Maple leafcutter.** Leaf litter sampling was done just after leaf fall in late September and early October to collect overwintering pupae. A PVC frame measuring ¼ $m^2$ was randomly tossed onto the ground within the dripline of each sample tree and all of the duff and leaf litter collected from inside the frame. Samples were bagged and returned to the lab for processing. Processing consisted of hand sorting and counting the MLC pupae.

**Carbon sequestration.** Using tree and stand data generated by the NED computer stand inventory program, we determined the amount of carbon sequestered using the U.S. For. Service Carbon Tools Model available at http://nrs.fs.fed.us/carbon/tools/.

**Economic analysis.** A 2-page questionnaire for sugarmakers was developed to collect information on current sugarbush management methods and economic and operational aspects of these methods. Questionnaires were distributed at key meetings, such as the annual meeting of the North American Maple Syrup Council, and maple schools throughout the Northeast. Personal interviews will be conducted with a subset of sugarmakers in VT, NY and NH.

Sugar maple branch with numerous leaves attacked by maple trumpet skeletonizer


Pear thrips damage (above) and adult thrips on a maple bud (left).


Typical sugar maple borer damage on a pole-sized maple. The larval tunnel kills the cambial layer. Most wounds eventually heal over.


Typical eutypella canker. Canker is perennial and grows each year until tree is girdled or breaks off at the canker.

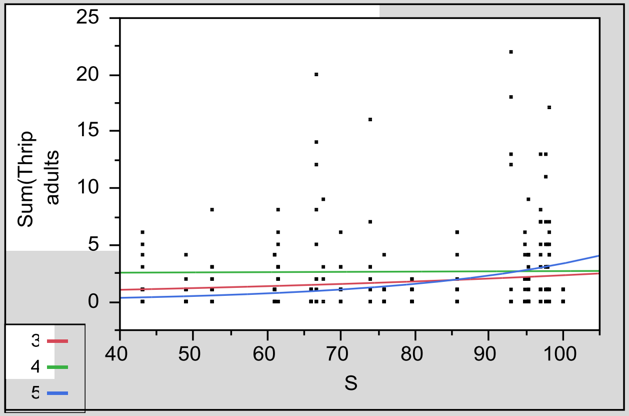
# Results/Project outcomes

- The ecological management approach resulted in significant reductions in insect and disease pest levels. Results were highly significant ($p<.0001$, ANOVA) for eutypella canker, sugar maple borer, % pear thrips defoliation, maple trumpet skeletonizer, maple anthracnose, and crown transparency. Regression analysis also showed highly significant relationships between pest levels and percent sugar maple stand composition with fewer pests and less damage with increasing non-sugar maple basal areas.
- Analysis comparing carbon sequestration between the two treatments was not significant. There was a highly significant relationship between carbon levels and stand basal area ($p<.0001$). Although stand composition differed between our treatments, total basal areas were not significantly different. Had we been able to locate plots with the very low basal areas typical of traditionally managed sugarbushes, we might have seen significant differences in carbon sequestration levels.
- Maple sugarmakers who responded to our survey came from 10 States and two Canadian provinces and collectively managed 13,000 acres with 316,000 taps. Fifty-two percent of respondents manage some or all of their sugarbushes traditionally while 69% of respondents would manage ecologically if their maples had fewer pest problems, were healthier, and lived for a longer period of time.

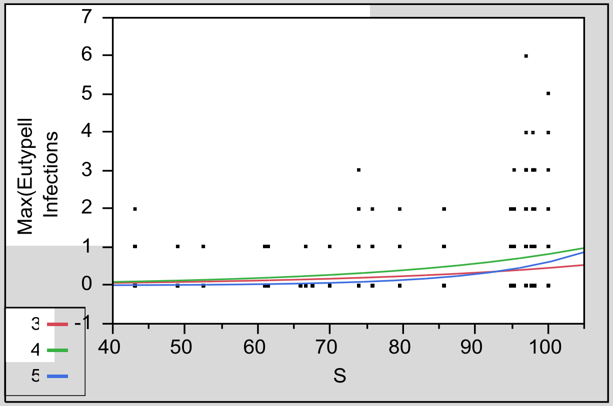
Comparisons of Sugar maple insect and disease pests between the two treatments: Treatment 1 = Traditional management (basal area 90 to 100% SM) and treatment 2 = Ecological management (basal area ≤75% SM).

| | **Treatment, means ± Std. err.** | | | |
|---|---|---|---|---|
| **Variable measured** | **1. Traditional** | **2. Ecological** | **Chi-square value** | **P - value** |
| Eutypella canker #infections/tree | 0.4944 ± .041 | 0.1126 ± .019 | 79.13 | P<.0001 |
| Sugar maple borer # attacks/tree | 1.85415 ± .069 | 0.7915 ± .045 | 171.05 | P<.0001 |
| Forced emergence #adult thrips/plot | 3.1099 ± .285 | 3.390 ± .297 | 0.47 | NS |
| | | | **F - Value** | |
| % Pear thrips defoliation/tree | 7.34 ± 0.212 | 3.38 ± 0.097 | 52.55 | P<.0001 |
| Anthracnose rating/tree | 1.96 ± 0.005 | 1.09 ± 0.024 | 67.88 | P<.0001 |
| Maple trumpet Skel.-#/100 leaves | 4.53 ± 0.94 | 2.27 ± 0.077 | 70.62 | P<.0001 |
| Crown transparency | 23.14 ± 0.514 | 15.22 ± 0.292 | 29.95 | P<.0001 |

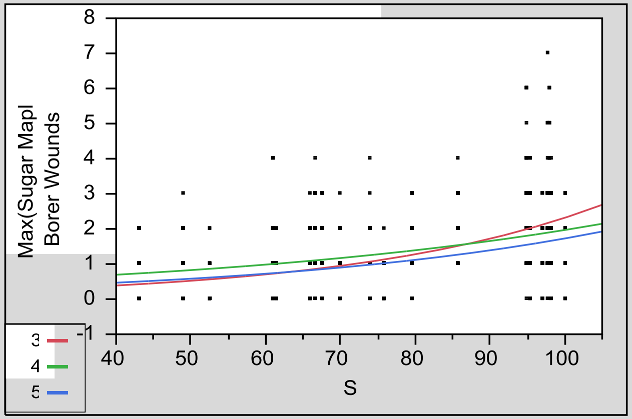
Relationship of sugar maple pest levels and % basal area sugar maple in northern hardwood stands used for maple sugaring across cold hardiness zone (CHZ). Generalized Linear Model analyses (assumes non-normally distributed data).




**Pear thrips adults/plot** by CHZ and %SM: L-R ChiSq=56.63, p<.0001

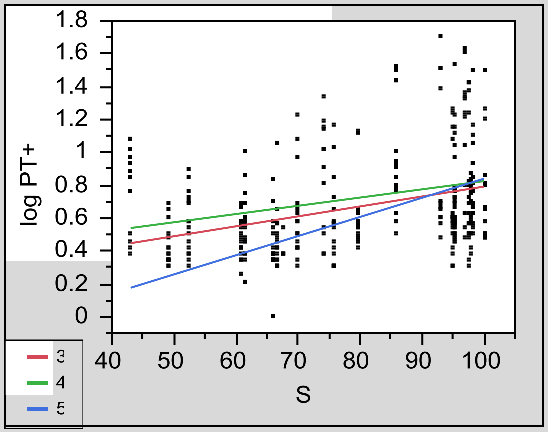



**# Eutypella cankers/tree** by CHZ and %SM: L-R ChiSq=132.36, p<.0001

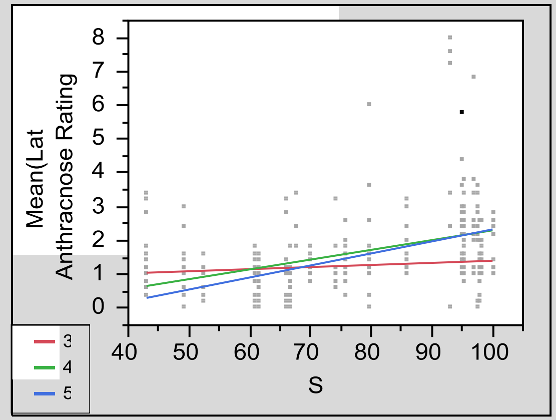



**# Sugar maple borer wounds/tree** by CHZ and %SM: L-R ChiSq=174.72, p<.0001

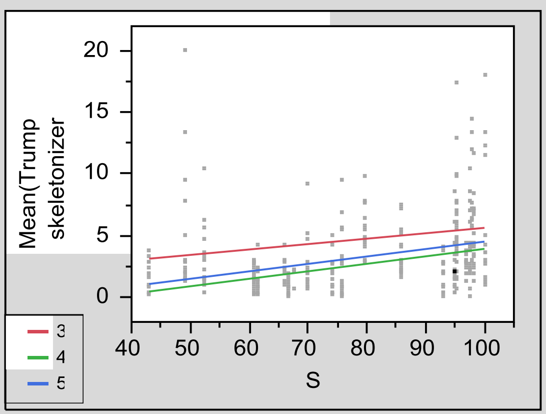
# Relationship of sugar maple pest levels and % basal area sugar maple in northern hardwood stands used for maple sugaring across cold hardiness zone (CHZ). General Linear Model analyses (assumes normally distributed data) w/analysis of co-variance.



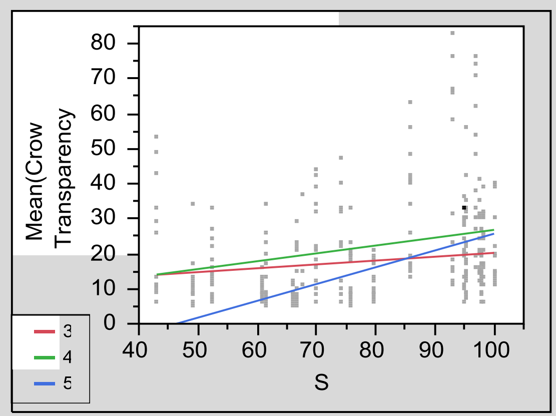

**% Pear thrips defoliation/tree** by CHZ and %SM, $R^2$=0.153, p<.0001




**Late anthracnose rating/tree** by CHZ and %SM, $R^2$=0.146, p<.0001




**% leaves with maple trumpet skeletonizer/tree** by CHZ and %SM, $R^2$=0.170, p<.0001




**% Crown transparency/tree** by CHZ and %SM, $R^2$=0.105, p<.0001

# Outreach efforts to date:

- A summary of the research findings from the initial 7 yr. pilot study and the first two years of this study was provided to Vermont Organic Farmers (VOF/NOFA) for guidance in the development of their VOF Guidelines for Certification of Organic Maple Syrup (Nov. 2012). Resulted in a 20% biodiversity rule.

- A similar report of findings was given to selected State of Vermont County Foresters for use in informing landowners seeking guidance in developing or maintaining maple sugaring operations.

- Research findings have been presented at various New York and Vermont Maple Sugarmakers Association meetings.

- Research findings presented at 2013 Vermont forest Health Information Meeting, White River Jct., VT, where numerous consulting and County foresters were in attendance.

# Implications and applications in the Northern Forest region

- In an economy where milk prices are down and feed prices up, as well as timber and pulp prices down, an increasing number of dairy farmers and forestland owners are turning to the lucrative maple sugar industry to make ends meet. This is resulting in thousands of acres of forestland being converted to sugarbush, often at the expense of other possible objectives such as timber production or wildlife habitat. This research will give direction to those doing conversions as well as those managing established sugarbushes that will provide for a healthier forest while also satisfying the needs of wildlife and providing a source of some additional forest products such as firewood or veneer logs.

- These results should be incorporated into presently available sugarbush management guidelines, such as what has already been done in the VOF Guidelines for Certification of Organic Maple Syrup. Adding some language on biodiversity standards for stands used for maple sugar production would also be appropriate in the State of Vermont’s Use Value Appraisal Program Manual.

# Implications and Applications, continued

- Our experience has shown that the 25% non-sugar maple threshold is easily attainable especially since red maples (also commonly tapped) count in the "non-sugar maple" category.  We also point out that it would be good practice to retain good nutrient cycling trees such as basswood and to a slightly lesser degree white ash trees as these trees further contribute to good forest health by adding essential plant nutrients to the forest floor.

- More than 69% of maple sugarmakers surveyed indicated that they would be willing to change common practices if it meant their forests would be healthier, and the survey was done before they had heard of our study and results.  It is our belief that most sugarmakers could be persuaded to manage more ecologically if they were to learn of these data and results.

# Future directions

- Determine if ecological management techniques have a significant effect on maple sap quantity and/or quality both on an individual tree and per acre basis. In our study the actual number of taps per acre was similar or even greater in the ecological management plots.

- Complete detailed soil analyses between the two treatments to determine if there are any differences in soil structure, bulk density, permeability, and fertility.  It has been reported that pure sugar maple stands can deplete the soils of certain key nutrients.

- Complete an inventory of invasive exotic plant/animal species within the two treatments and assess the impacts – both potential and actual.  The wide-open monocultural conditions of traditional sugarbush management may enhance the potential for the establishment of unwanted invasives.

# List of products

- See slide 13 "Outreach Efforts to Date".
- At least two peer reviewed journal articles will be prepared from this research, one in an extension journal highlighting the sugarmaker survey, and another in the Northern Journal of Applied Forestry presenting the treatment and pest level data.  Expected publication dates: 2013-2014.
- A region-wide set of nine sites, 18 sub-sites, and 72 plots with permanent markings that can be used for further investigations.
- A set of pest quantifying and monitoring protocols that can be used in additional studies.