# Ontario Forest Biomonitoring Network: Twenty Years of Monitoring the Health of Ontario's Hardwood Forest

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## Abstract

*Since 1986, the Ontario Ministry of Environment has maintained a network of 110 plots to monitor the effects of regional air quality and climate change on the hardwood forest in Ontario. The 50 by 50 metre plots are established in unmanaged sugar maple (*Acer saccharum*) dominated stands on public and private land. Visual symptoms of branch dieback, leaf colour, and leaf size were quantitatively evaluated for approximately 15 000 trees, greater than 10 centimetres diameter at breast height (DBH). Other parameters including DBH, tree height, soil, and foliar chemistry were also evaluated. Overall, between 1986 and 2004, forest condition improved in the majority of the plots although regional differences were noted with tree condition poorer on northern soils underlain by Precambrian rock. In 2004, data from the monitoring program were made available to research partnerships with academia, government, and non-governmental organizations. These partnerships were initiated to increase the program's effectiveness in data sharing, data analysis, and monitoring.*

***Keywords:*** *biomonitoring, air quality, climate change, forest decline, partnerships.*

## Introduction

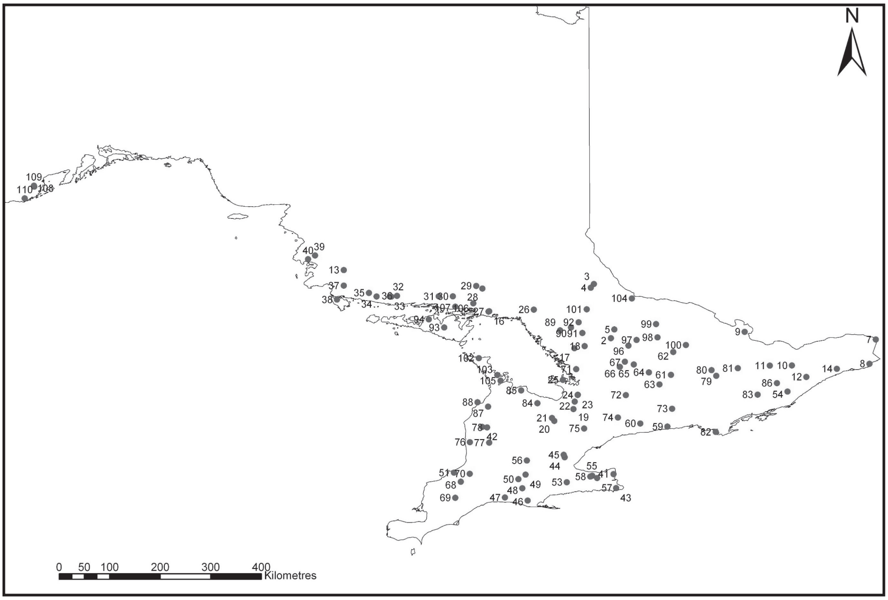
Throughout the 1980s and the early 1990s, concerns regarding forest decline and the possible relationship with air pollution were expressed in popular literature, news media, and scientific publications. The problem was perceived to be particularly severe in the forests of central Europe, the high elevation spruce forests of the northeastern United States, and the deciduous forests of eastern Canada, the US lake states, and New England. In Canada, the concern centred primarily on white birch (*Betula papyrifera*) in New Brunswick (Cox *et al.,* 1996) and sugar maple (*Acer saccharum*) in southern Quebec and south-central Ontario (Bell *et al.,* 1998; McIlveen *et al.,* 1989). The hardwood forests of southern and central Ontario receive the highest rate of acidic deposition and ground-level ozone in eastern Canada. In addition, much of these forests are growing on naturally acidic, shallow, and relatively nutrient-poor sandy soil, which is characteristic of the Canadian Shield. This combination of high pollution loading and poorly-buffered, acid-sensitive soils makes a large portion of the hardwood forests in Ontario particularly susceptible to the potential adverse effects of acidic deposition (Bower and Hopkins, 1995; McLaughlin, 1999).

In 1985, the Ontario Ministry of the Environment (MOE) initiated the Ontario Forest Biomonitoring Network (OFBN), a forest health survey of the mixed hardwood forests across Ontario. One hundred and ten permanent forest observation plots were established across the range of the mixed hardwood forest in Ontario. The plots were established in undisturbed, mature forest stands, representative of an area 10 hectares in size and at least 10 kilometres distance from urban areas or point sources of pollution. The plot locations were stratified by Rowe (1972) forest sectors and at a minimum of one plot per 100 square kilometres. Additional plots were also located in areas suspected to contain hardwood decline as of 1985. Plots were located on public and private land (crown land: n = 54, parks: n = 36, private: n = 17, removed: n = 3). Plot locations are illustrated in Figure 1. The ¼ hectare (50 metre by 50 metre) plots contain between 93 and 261 trees greater than 10 centimetres diameter at breast height (DBH), for a total of approximately 15 300 trees in the survey. Sugar maple (*Acer saccharum*) is the most common tree species in Ontario's mixed hardwood forests, and accounts for 73% of all the trees in the OFBN. In total, 28 tree species are represented, although 19 tree species are each less than 1% of the tally and cumulatively only represented 5% of the tree species present in the plots. Table 1 illustrates the species composition of the OFBN forest plots.

## Ontario Forest Biomonitoring Network Program

The original focus of the OFBN was to investigate the condition of the Ontario mixed hardwood forest, determine if widespread forest decline was

**Figure 1**. Locations of Ontario Forest Biomonitoring Network Plots.




occurring, and if regional air pollution, specifically acidic deposition, was a causal factor in any decline observed. As discussed in McLaughlin *et al.* (2000), after the first twelve years of the survey, hardwood forest health in the province appeared to be quite good; severe decline was limited, very site specific and occurring only on acid-sensitive, marginal, and/or shallow soil sites. McLaughlin *et al.* (2000) did find a statistically significant relationship between low soil pH, high available soil aluminum concentrations, and forest decline, although the phenomena appeared limited in geographic extent to northern, poorly buffered, shallow soil sites.

In 2004, the scope of the OFBN was modified to embrace a larger scientific and academic community. The main objective of the OFBN is to further the understanding of environmental stresses, specifically regional air quality and climate change, on hardwood forest health in Ontario. In order to accomplish this objective, partnerships are being encouraged with a variety of governmental and non-governmental partners. The core of the OFBN, however, remains the province-wide database on the visual condition of the province's mixed hardwood forests initiated in 1986. Through annual re-evaluation of the same trees, it is possible to identify trends in changing tree condition over time and among geographic areas across the province. In Ontario, the main visual symptoms of hardwood tree decline are: chlorotic (pale green or yellowed) leaves; leaves that are much smaller than

**Table 1**. Species composition of Ontario Forest Biomonitoring Network plots.

| Species | Count | % of Total |
|---|---|---|
| **>5% per Species** | | |
| Sugar Maple (*Acer saccharum*) | 11269 | **73.36** |
| **<5% per Species** | | |
| White Ash (*Fraxinus americana*) | 598 | 3.89 |
| Ironwood (*Ostrya virginiana*) | 524 | 3.41 |
| Soft (red) Maple (*Acer* spp.) | 497 | 3.24 |
| Basswood (*Tilia americana*) | 475 | 3.09 |
| American Beech (*Fagus grandifolia*) | 468 | 3.05 |
| Black Cherry (*Prunus serotina*) | 307 | 2.00 |
| Red Oak (*Quercus rubra*) | 238 | 1.55 |
| Yellow Birch (*Betula alleghaniensis*) | 227 | 1.48 |
| **Total** | | **21.70** |
| **<1 % Per Species** | | |
| White Birch (*Betula papyrifera*) | 183 | 1.19 |
| Trembling Aspen (*Populus tremuloides*) | 179 | 1.17 |
| Bitternut Hickory (*Carya cordiformis*) | 117 | 0.76 |
| Eastern Hemlock (*Tsuga canadensis*) | 72 | 0.47 |
| Black Ash (*Fraxinus nigra*) | 51 | 0.33 |
| Balsam Poplar (*Populus balsamifera*) | 28 | 0.18 |
| Balsam Fir (*Abies balsamea*) | 25 | 0.16 |
| Eastern White Pine (*Pinus strobus*) | 22 | 0.14 |
| American Elm (*Ulmus americana*) | 17 | 0.11 |
| Largetooth Aspen (*Populus grandidentata*) | 14 | 0.09 |
| Eastern White Cedar (*Thuja occidentalis*) | 14 | 0.09 |
| Pin Cherry (*Prunus pensylvanica*) | 10 | 0.07 |
| White Spruce (*Picea glauca*) | 8 | 0.05 |
| White Oak (*Quercus alba*) | 7 | 0.05 |
| Butternut (*Juglans cinerea*) | 6 | 0.04 |
| Bur Oak (*Quercus macrocarpa*) | 2 | 0.01 |
| Hickory (*Carya* spp.) | 2 | 0.01 |
| Green Ash (*Fraxinus pennsylvanica*) | 1 | 0.01 |
| Tamarack (*Larix laricina*) | 1 | 0.01 |
| **Total** | | **4.94** |
| **Cumulative Total** | **15362** | **100** |

normal; and dieback of the fine twig structure, followed by the death of main branches. Leaf size, leaf colour, and twig or branch mortality are assessed relative to prepared templates by trained field crews for all trees over 10 centimetres DBH in each survey plot. The individual crown component scores are combined into a numerical Decline Index (DI) for each tree using a weighted mathematical model. The DI is calculated to the nearest whole number and ranges from 0, for a tree with no symptoms, to 100, which is a standing dead tree. The individual tree DI scores are averaged to arrive at a DI for the plot. For more information on the DI methodology consult McLaughlin *et al.* (2000).

On an annual basis, the OFBN program has included only the DI and tree mortality assessment. The program, however, includes a number of additional parameters including diameter at breast height (DBH), tree condition (physical, disease, and insect damage), tree recruitment, tree species, and soil and foliar chemistry. A full list of OFBN parameters, collected by the MOE, is presented in Table 2. Other parameters will be collected on OFBN plots by partner organizations.

**Table 2**. Ontario Forest Biomonitoring Network data holdings, 1986 through 2004.

| Data | Frequency |
|---|---|
| Decline Index | Annual since 1986, except 1988 and partial in 1994 |
| Tree Mortality | Annual since 1986, except 1988 and partial in 1994 |
| Stem Maps | 1986, 1991 |
| Species Composition | 1986 |
| Diameter at Breast Height | 1986, 1994 (25 plots) |
| Canopy Position | 1986 |
| Tree Height | 1986 |
| Wound, Disease, Insect Assessment | 1986, 1987, 1989, 1990, 1991 |
| Tree Recruitment | 2004 (plots 108, 109, 110), rest scheduled for 2005 |
| Soil Chemistry | 1986, 1994 (25 plots) |
| Foliar Chemistry | 1986, 1994 (25 plots) |

## Ontario Forest Biomonitoring Network Partnerships

In 2004, in order to effectively meet the revised monitoring scope of the OFBN, the MOE actively began recruiting partner organizations. The main purposes for seeking partner organizations was to encourage data sharing, to enhance data analysis, and to expand monitoring parameters. It was recognized that there is potential for great synergy and increased effectiveness in ecological monitoring by establishing productive partnerships with other government agencies, academia, professionals, non-governmental organizations, and citizen scientists/volunteers. Another benefit was the increased profile the OFBN gained by entering into partnerships.

The OFBN was initiated in 1985 when the Province was aggressively funding acid rain research. In 1991 the Province's acid rain office was closed and funding was re-directed and subsequently operating resources for the OFBN were significantly restricted. Although data continued to be collected, data analysis and interpretation lagged. In addition to a large under-analyzed database, the OFBN database contained historical biological and chemical data that could be utilized as a baseline by partnered researchers.

As of publication, the MOE has successfully established partnerships with four Ontario universities as well as with a number of local, provincial, and federal government agencies. One partnership, in conjunction with other federal and provincial ecological monitoring programs, will use OFBN plots to ground truth an independently derived model for predicting soil critical loads for base cations. This partnership will also examine in more detail the relationship found in McLaughlin *et al.* (2000) regarding decreases in soil pH, increases in available soil aluminum concentrations and increased rates of forest decline. The second partnership will assist the MOE in the interpretation of the long-term OFBN Decline Index and mortality database. The research will interpret the OFBN data relative to climate, ecological land classification, and provincial forest insect databases. Both partnerships will assist the MOE in determining the effectiveness of the OFBN monitoring program and, if necessary, suggest modifications to the program.

Two other university partnerships will add new data to the OFBN program. One partnership will conduct invasive plant species monitoring at and around the OFBN plots to determine provincial invasive plant species distributions. The other partnership will use lichens as a surrogate for air quality at and adjacent to OFBN plots. Additional partnerships have been established or are being discussed with local, provincial, and federal government and non-governmental agencies. In particular, a fruitful partnership has been established with Environment Canada's Ecological Monitoring and Assessment Network (EMAN) Coordinating Office. EMAN has been instrumental in assisting the OFBN in establishing other partnerships, holding workshops, and increasing the OFBN's profile.

## Conclusion

The research continues. In addition to the partnership research in 2005, the MOE plans to continue the collection of Decline Index, mortality, DBH, tree height, canopy position, wound/disease/insect, and tree recruitment data. A number of these parameters have not been collected on a province-wide basis since the early 1990s and in some cases since 1986. The coming years should see detailed analysis of the long-term OFBN database and perhaps modifications to the monitoring program. The MOE encourages the establishment of new partnerships to further expand and explore the OFBN database. For further information, please contact the corresponding author, the general OFBN e-mail address (ofbn@ene.gov.on.ca), or visit the OFBN website at www.ofbn.ca

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