FOREST HEALTH ASSESSMENT FOR EASTERN HARDWOOD FORESTS

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Information presented here, was obtained generally from 3 sources: the Cooperative Forest Health Protection Program, the Forest Inventory Analysis Program, and the National Forest Health Monitoring Program. The Cooperative Forest Health Protection Program is a joint State-Federal effort responsible for forest-wide surveys of forest damage. From these surveys, we gather information about the nature and extent of insect, disease, and weather caused damage to trees and forests. These surveys are conducted by State and Federal pest specialists. Forest Inventory and Analysis Surveys are conducted by the U.S. Forest Service within each State on generally a ten-year basis and provide periodic updates on such forest statistics as growth rates, volume changes, and rates of mortality and cutting. The National Forest Health Monitoring Program uses a network of permanent plots, visited annually, to monitor tree conditions such as crown vigor, signs of insect and disease damage, ozone damage, and foliar and soil chemistry. To date, plots have been established throughout New England, New Jersey, Delaware, Maryland, and the Lake States. Crown vigor is an aspect of tree condition that has become of particular interest in monitoring forest health. The Forest Health Monitoring Program has divided crown vigor into three components: foliage transparency, crown density, and crown dieback. Foliage transparency is a measure of the "fullness" of a tree's crown. That is, the greater the transparency the more light passes through, indicating that foliage may be missing. Changes in foliage transparency occur as a result of insect feeding, deformed foliage, or reduced amounts of foliage. Crown density, estimates a tree's crown in relation to a normal or expected shape and size. It is the amount of crown branches and foliage that block light coming through the canopy. Crown dieback, is defined as branchlet or twig mortality in the upper portions of the crown. Crown dieback is often thought of as the first sign of tree stress. Taken together, these three crown rating factors can be used to assess crown vigor.

FOREST CONDITIONS

Beech (*Fagus grandifolia*)

The forest type known as maple/beech/birch encompasses nearly 5 million acres in the east. The largest concentrations of beech are found in New York, Pennsylvania, and West Virginia. In New England and the mid-Atlantic States, the volume of beech has generally increased with the exception of Maine where a 6% decrease in growing stock volumes has occurred (Tables 1 and 2). New York and Vermont have higher than average annual beech mortality rates, as a percent of growing stock volume.

A very important factor in the health of beech, is the beech bark disease. This disease, first introduced into Maine in the 1930's from Canada has spread throughout New England into Pennsylvania and West Virginia. By the mid-1970's, it was estimated that over 30 percent of the beech in New Hampshire and Vermont and 50 percent of the beech in Maine over 8 inches in diameter were killed by this disease. It is worth noting that in New England, the percent of growing stock volumes in trees less than 15 inches in diameter is quite high. In Maine, where beech is decreasing, 86% of the growing stock volume is in smaller trees. Mortality has also occurred on over 500,000 acres of forest containing beech in West Virginia, and on over 250,000 acres in New York. What we are seeing in the New England and mid-Atlantic States is that older, larger beech are being killed by the disease and then replaced by new, smaller beech. In many instances, these young trees are sprouts and are just as susceptible to the disease. Most become infected by beech bark disease, but because they are able to outgrow infection, they are not always killed. However, this so-called "aftermath" forest consists of many highly deformed, defective trees.

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Results of Forest Health Monitoring, illustrate that for American beech, nearly 47% of the trees have poor crown density and slightly more than 27% have severe crown dieback. Though only small percentages of the trees are being monitored, the results are significant in that they are higher percentages than for other hardwood species.

Table 1. Change in volumes and annual mortality for American Beech - Mid-Atlantic States (data from FIA survey reports).

State	% change in growing stock volume between inventory periods ('72-'92)	% of growing stock volume in trees less than 15 inches	annual mortality as % of growing stock volume
DE	-47	47	
NJ	85	56	.1
MD	30	49	0
PA	24	63	.5
WV	19	52	.2
OH	64	38	.6
Average	34	52	.3

Table 2. Change in volumes and annual mortality for American Beech - North Central States (data from FIA survey reports).

State	% change in growing stock volume between inventory periods	% of growing stock volume in trees less than 15 inches	annual mortality as % of growing stock volume
MI	-18	63	.7
MO		32	.6
IL	-16	20	.4
WI	13	51	2
IA			
Average	-7	42	.9

Maples (*Acer* spp.)

Of the hardwood species growing in the East, oaks are the most common accounting for one-third of the hardwood volume (Powell et al. 1993). The maples (*Acer* spp.) are next in abundance, and are one of the fastest growing components of our hardwood forest. Sugar (A. saccharinum) and red maples (A. rubrum) together account for 17% of all hardwood volumes in the East (Powell et al. 1993). Table 3 illustrates changes in growing stock volumes for both sugar and red maples. The largest gains in sugar maple volumes occurred in Ohio with a whopping 98% increase in growing stock volumes between 1979 and 1991, and a 138% increase in red maple volumes for the same time period.

Why the increases? Both sugar and red maple are very tolerant of shade and both are prolific seeders. Maples will increasingly occupy sites as openings are created or other species are cut and removed. Large increases in one species mean others loose ground. In Ohio, red maple has replaced hickory as the most abundant tree species in the forest.

In recent years there has been concern expressed over the health of sugar maple. Sugar maples, used for the production of maple syrup and as a roadside and yard tree, are a valuable component of our forests in the east. In many cases, various stressing agents have been associated with dieback and decline of individual sugar maples, especially insect defoliators and physical damage. In northern New York the forest tent caterpillar defoliated over 120,000 acres of sugar maple in 1993. Pear thrips defoliation continues in Vermont, Pennsylvania, and New York, however, the area affected is down from the 1980's when the most extensive damage occurred. In northern Pennsylvania, an area of 260,000 acres has been defoliated for several years by the elm spanworm. Most heavily impacted within this area has been red maple and American beech.

The North American Maple project has been collecting information at permanent sample sites throughout eastern Canada and the northeastern US. Results of this effort have shown that more than 90 percent of all sugar maples within the survey were considered to have healthy crowns. Of those with more than 50% dieback, nearly all had major root or trunk damage. Within the survey area, sugar maple mortality is estimated to be only 1 percent of trees per year. This isn't to say the local problems won't develop. In Pennsylvania, for example, red and sugar maple volumes are up, statewide. However, several northwestern counties in an area known as the Allegheny Plateau are experiencing decreases in sugar maple growing stocking relative to other species. Some of this may be due to the affects of Pear thrips defoliation, or just to an overabundance of sugar maple resulting in increased competition for soil and water resources. Experts have been gathering information related to this localized problem, but answers are not yet available.

Oaks (*Quercus* spp.)

Our present oak-hickory forests rose out of the natural catastrophe known as the chestnut blight. Forests once referred to as oak-chestnut covered huge areas of the eastern US from southern New England to northern Georgia. Chestnut blight, caused by a fungus, was introduced to this country in 1904, and by the 1930's virtually all chestnut trees were infected and dying. Natural replacement of the chestnut followed resulting in forests in which oaks, yellow poplar, and hickory became dominant. Today, we refer to these replacement forests as oak-hickory forests, but as the noted ecologist Lucy Braun wrote in 1950, "it is impossible as yet to predict the final outcome of the partial secondary successions everywhere in progress."

Within the present day oak-hickory forests, a new forest health factor looms--the gypsy moth. This defoliating insect was introduced into the US in 1890 in Massachusetts. It has gradually spread throughout the East, now occupying a place in the forests from Maine to Virginia and west to Wisconsin. The larvae of the gypsy moth feed on a variety of hardwood species but favor oaks (*Quercus* spp), sweetgum (*Liquidambar styraciflura*), basswood(*Tilia americana*), and willow (*Salix* spp). Repeated gypsy moth defoliation can result in growth loss, tree mortality, changes in forest composition, and loss of habitat for various animal species. In some areas, oak mortality due to gypsy moth defoliation has been quite significant. Areas of south-central Pennsylvania have experienced extensive oak mortality during outbreaks in the late 1980's. Gypsy moth will not disappear from these forests, and a new balance must be struck between forest and insect. Overall, in Pennsylvania a state with a 20 year history of gypsy moth defoliation, oaks still account for 43 percent of the total forest volume (Gansner et al. 1993).

Table 3. Change in growing stock volumes for hard and soft maples (data from Forest Inventory Analysis Reports (1972-1992)).

	sugar	red	years
	----------percent change----------		
Mid-Atlantic States			
NJ	-	-	
PA	20	37	1978-1989
WV	56	74	1975-1989
OH	98	138	1979-1991
MD	47	56	1976-1986
DE	-	-	
Average mid-Atlantic	55	76	
Northcentral States			
WI	48	79	1967-1982
MI	21	78	1965-1979
IL	63	32	1962-1985
IN	65	102	1967-1986
MN	40	94	1977-1989
IA	4	44	1974-1990
Average Northcentral	40	55	

Hickories (*Carya* spp.)

Of the total amount of hardwood volume in the East, oaks comprise nearly a third while hickories account for only about 4% . Recently, some concern has been raised over declining hickories in various parts of its range-notably Wisconsin, West Virginia, and Ohio. Table 4 shows that though hickory growing stock has increased in most states during the past 20 years, much of this increase has occurred in trees of smaller size. Larger trees (over 15 inches in diameter) appear to be succumbing to mortality or cutting in Minnesota, Delaware, Rhode Island, New York, Massachusetts, and Connecticut. States with higher than average rates of hickory mortality are Massachusetts, Rhode Island, Missouri, and Illinois. At present, the causes of hickory decline in these areas is unknown though several wood-boring insects are suspected of playing a role.

White Pine (*Pinus strobus*)

White pine extends from Maine to the Lake States and south throughout the Appalachian Mountains. It grows in a variety of conditions from pure stands to stands in which it is only a minor component. I mention it here, because in the East, it is found associated with many different hardwood species including aspen, birch, oaks, and hickory, and because it is coming back. White pines' moderate shade tolerance, its long life, and its resistence to fire, make it a very adaptable species. The lumber industry of the east was based upon white pine for much of the 1800's and early 1900's. Today, however, (and due, in part, to exploitive logging) white pine sawtimber is only regionally important. In total, white and red pines account for only about 3 percent of the volume of softwood growing stock in the US. In most areas of the East, white pine is coming back. Growing stock volumes are up 105% in West Virginia, 52% in Connecticut, and 43% in Pennsylvania, all in the last 20 years. Within the Northeastern area, today, Michigan has the largest concentration of white and red pines totaling an estimated 2,017 million cubic feet of growing stock, followed by Maine with 1,916, and New York with 1,809.

Table 4. Change in volumes and mortality rates for hickory (data from Forest Inventory Analysis Reports, 1972-1993).

State	% change in growing stock volume between inventory periods	% of growing stock in trees less than 15 inches in diameter	annual mortality as a % of growing stock volume
CT	19	85	0.5
NY	23	82	.4
MA	-22	92	2.1
RI	73	95	.7
NJ	---	78	.3
MD	12	67	.6
PA	12	79	.8
WV	32	77	.4
OH	35	68	.6
DE	- 70	71	NA
IN	19	67	.5
MO	45	85	.8
IL	52	70	1.0
MN	54	87	.3
MI	3.0	79	.1
WI	82	90	.2
IA	74	82	.4

Ash (*Fraxinus* spp)

White ash and black ash are components of the elm-ash-cottonwood forest type which encompasses over 10 million acres in the northeastern and northcentral states from Maine to Minnesota. White ash is the most common native ash species, while black ash is found more often along streams and rivers.

In the central Appalachians, ash growing stock increased 36 percent since the last inventories. However, some problems have been occurring. A disease, ash yellows, caused by a mycoplasma-like organism, has been confirmed occurring in almost every state within the Northeastern Area. Not all ash problems can be attributed to this disease, since damage from drought, insects, and rust diseases are also found in association with declining ash trees.

Decline of black ash was reported in 1993 in Maine on 120,000 acres. Numerous trees with severe crown dieback have been observed along streams in Maine. In New York, ash anthracnose, a foliage disease was reported in 1993 on 105,000 acres.

Results of FHM assessments of white ash crown conditions in 1993 show that white ash is second only to American beech in percent of trees with severe dieback and poor crown density.

Butternut (*Juglans cineraea*)

Butternut, or white walnut, is associated with many other hardwood species and occurs sporadically throughout the east. The tree is most valued for its nut production for wildlife and for furniture wood. In the past the majority of butternut timber production has been in West Virginia, Wisconsin, and Indiana. However, it is hard to find healthy butternut in forest stands today, as the species is being threatened by a devastating disease known as butternut canker caused by *Sirococcus clavigignenti-juglandacearum*, a fungus of unknown origin.

The disease was first reported occurring in Wisconsin in the mid-1960s, but has probably been in the United States prior to that time. It is now present throughout the range of butternut. The cankers girdle the branches and tree stems, causing mortality. There is no known control for butternut canker disease. Efforts now center on finding resistant individual trees within infected stands.

In 1993, a ground survey confirmed the presence of the disease in central coastal Maine. Surveys for the disease were also conducted in New York, where most of the counties surveyed were found infected, and Vermont, where the presence of the disease was confirmed throughout the state. In Wisconsin, where over 1000 trees were samples in 32 counties, 91 percent of the live trees were found to be infected and 27 percent of the surveyed trees were dead. In the last decade the number of live butternut decreased 58 percent in Wisconsin and 84 percent in Michigan. Several evaluation surveys indicate that the disease has spread rapidly within infected stands.

Two other factors affecting the eastern deciduous forest that are worth mentioning are **weather** and **air quality.**

Floods

In the summer of 1993, in the mid-west, thousands of acres of bottomland hardwood areas were flooded for 4 to 12 weeks. The flood waters also backed up into upland areas, affecting urban areas forested with trees not well adapted to flooding. The states along the Missouri and Mississippi Rivers and their tributaries were severely affected. Flood stressed trees exhibited a range of symptoms including leaf yellowing, early leaf drop, and dieback. It is possible that these affected trees will show symptoms for several years. They may also be affected by various insects and diseases.

Air quality

There are 3 aspects of air quality that are presently of concern with respect to the health of eastern deciduous forest; ozone, and emissions of sulfates, and nitrates.

Ozone. Ozone is an air pollutant in the lower atmosphere, formed from the reaction of compounds produced by automobile emissions and industrial processes, in combination with sunlight. There is increasing concern as to how ozone may be influencing the health of the forest resource. Atmospheric concentrations are monitored through a network of ozone monitoring stations throughout the area. And, damage to sensitive plant species, called bioindicators, has been assessed on National Forest Lands and on State and Private Lands as part of the National Forest Health Monitoring program. The results for 1993 indicate that there was little ozone injury encountered. This is mainly because of the low incidence of damaging ozone in the atmosphere during the summer of 1993. The incidence of damage was higher in 1990, which was a year when ozone concentration were high due to dry and hot summer conditions.

Using bioindicator plants allows for a general assessment of the air quality. Research is currently being conducted to determine the link between visible symptoms and foliar injury. At this time, the bioindicator information cannot be used to make a statement about the effects on the productivity of or damage to the forest. We know that across a broad range of ozone concentrations dose-responses of net photosynthesis and growth of trees ar dependent upon ozone concentrations. We know that significant differences exist amount species in sensitivity to ozone. And, we know that ambient ozone concentrations are probably sufficient to a cause reductions in photosynthesis and growth in most vegetation of the east. However, we do need long-term ecological studies of the interactions between ozone and natural factors before we can quantify the response of forest ecosystems to ambient ozone pollution (Reich 1987).

Sulfates and nitrates. We know that the eastern US receives the highest depositions of sulfates and nitrates in the country, and that, at least for sulfates, 90% of this deposition is due to man-made sources (Galloway and Whelpdale 1980). The effects of these air borne pollutants upon forest ecosystems was described by Smith (1974) as ranging anywhere from subtle changes in species composition and forest structure to obvious structural simplification and major changes in ecosystem function. Presently, however, adverse effects of the deposition of sulfates and nitrates (acid rain) are limited to high-elevation spruce forests. The National Acid Precipitation Program (NAPAP) was unable to provide evidence of widespread forest damage in the US. (Barnard et al. 1989). Although no direct adverse effects on terrestrial vegetation has been documented, indirect effects may result from long-term changes in soil chemistry. In fact, NAPAP, concluded that changes in soil chemistry may progress for 50 to 60 years before effects on forests are observed. These concerns must be taken seriously and links between possible changes in soil chemistry and the incidence of disease and insect attacks investigated. For example, it is plausible that changes in soil chemistry may alter tree physiology to the extent that resistance to disease or insect attack is lessened.

CONCLUSIONS

Overall, if we look at all hardwoods in the East using data compiled by the USDA Forest Service for the Resource Planning Act Assessments, we find increasing volumes and mortality generally stable, except for the last few years (Fig. 1).

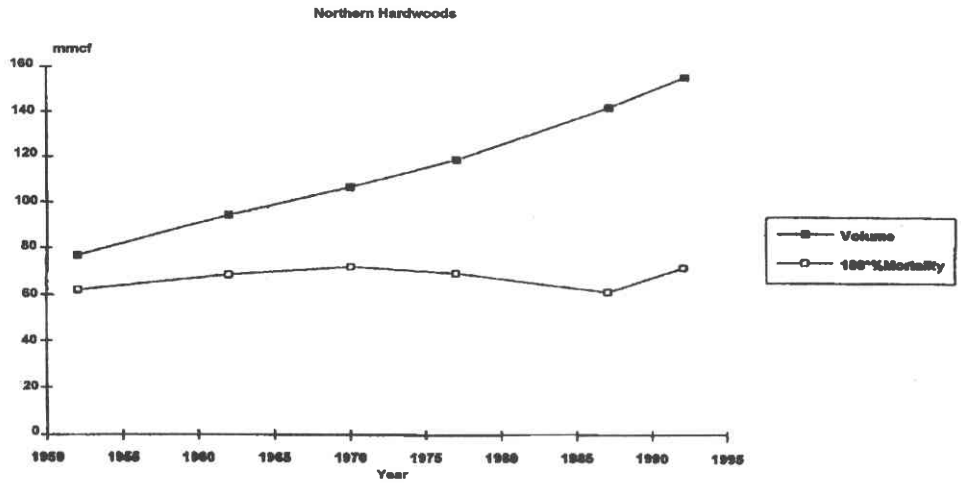

Figure 1. Data from Resource Planning Act Assessments. Personal communciaton, Eric Smith, USDA Forest Service, Ft. Collins, Co.

Evaluating forest health requires analysis of several conditions. In this paper, I have examined incidence of insects and disease, growth, rates of mortality, and species composition changes. Growth or measures of productivity, by themselves, do not reflect forest health. For the eastern hardwood forest, it is important to evaluate not only growth, but factors such as mortaltiy rates, diverstiy, changes in species composition, the effects of mangagement and fragmentation, and the exogenous effects of changes in air qualtiy. Health, as a concept in forestry is only beginning to be understood. On the surface, our tendency is to view the health of the forest from an organismic viewpoint. But forests exist as complex communities, constantly changing, and constantly being affectted by what happens within the environment within which they too exist.

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