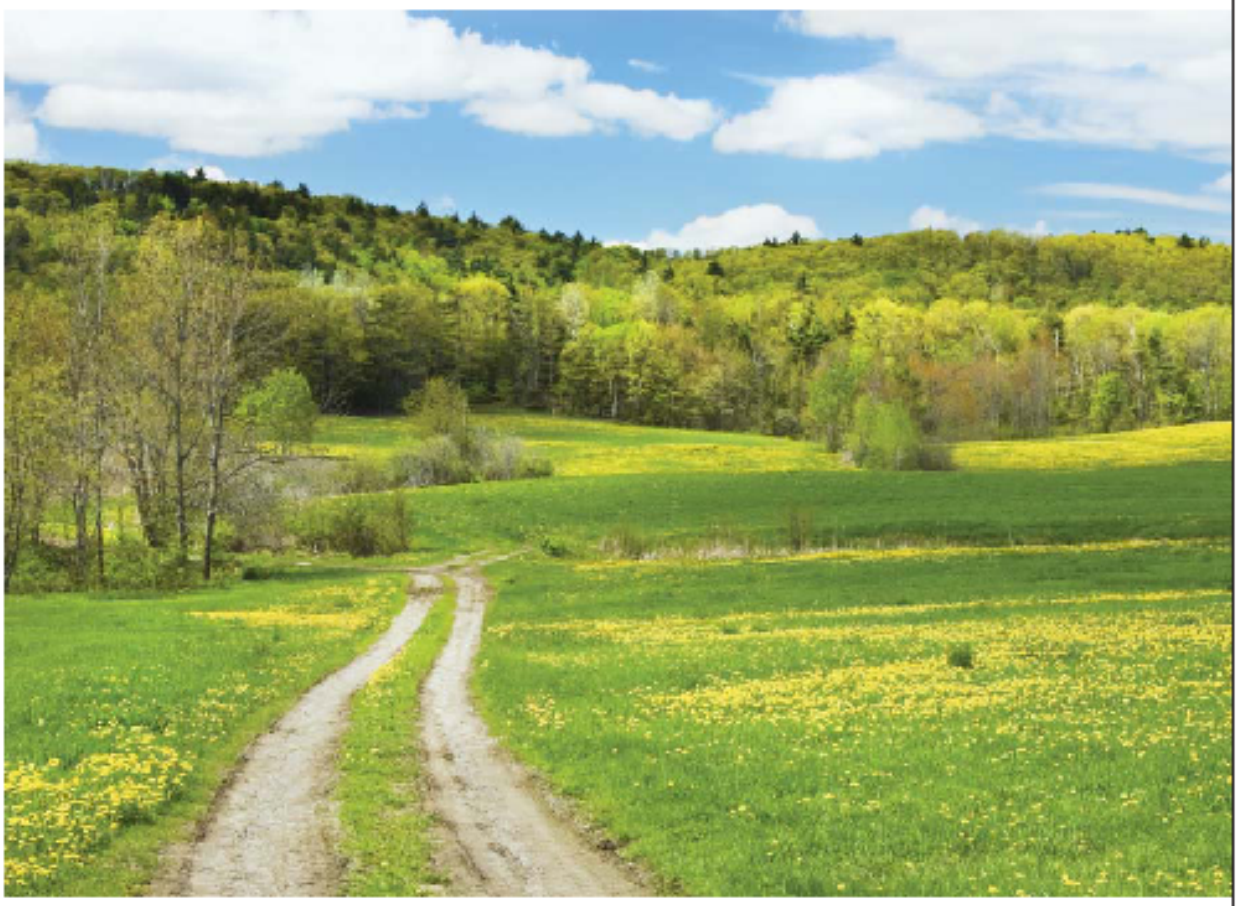
New England Forests: The Path to Sustainability

CHAPTER 5 • CLEAN AND COOL THE AIR



A TECHNICAL REPORT BY NEW ENGLAND FORESTRY FOUNDATION

INTRODUCTION

This project documents both the existing value and potential of New England's working forest lands: Value – not only in terms of business opportunities, jobs and income – but also nonfinancial values, such as enhanced wildlife populations, recreation opportunities and a healthful environment. This project of the New England Forestry Foundation (NEFF) is aimed at enhancing the contribution the region's forests can make to sustainability, and is intended to complement other efforts aimed at not only conserving New England's forests, but also enhancing New England's agriculture and fisheries.

New England's forests have sustained the six-state region since colonial settlement. They have provided the wood for buildings, fuel to heat them, the fiber for papermaking, the lumber for ships, furniture, boxes and barrels and so much more. As Arizona is defined by its desert landscapes and Iowa by its farms, New England is defined by its forests. These forests provide a wide range of products beyond timber, including maple syrup; balsam fir tips for holiday decorations; paper birch bark for crafts; edibles such as berries, mushrooms and fiddleheads; and curatives made from medicinal plants. They are the home to diverse and abundant wildlife. They are the backdrop for hunting, fishing, hiking, skiing and camping. They also provide other important benefits that we take for granted, including clean air, potable water and carbon storage. In addition to tangible benefits that can be measured in board feet or cords, or miles of hiking trails, forests have been shown to be important to both physical and mental health.

Beyond their existing contributions, New England's forests have unrealized potential. For example, habitats for a wide variety of wildlife species could be enhanced by thoughtful forest management. Likewise, wood quantity could be increased and the quality improved through sustainable forest management. The virtues of improved forest management and buying locally produced goods are widely extolled, but what might that actually look like on the ground? More specifically, how could enhanced forest management make more locally produced forest products available to meet New Englander's own needs, as well as for export, improve the local and regional economies and provide the greatest social and environmental benefits?

The purpose of this project is to document that potential by analyzing what we know about how improved silviculture can enhance wildlife habitat, the quantity and quality of timber, recreational opportunities, and the environment. The best available data from the US Forest Service, state forestry agencies and universities was used to characterize this potential.

The technical reports produced for this project document the potential for:

- Mitigating climate change;
- Increasing timber production to support a more robust forest products industry;
- Restoring important wildlife habitat;
- Replacing fossil fuels with wood to produce thermal energy;
- Reducing greenhouse gas emissions, not only by substituting wood for other fuels, but also wood for other construction materials;
- Enhancing forest recreation opportunities and related tourism;

- Expanding production of nontimber forest products;
- Maintaining other forest values such as their role in providing clean air and potable water – taken for granted but not guaranteed;
- Enhancing the region's economy by meeting more of our own needs with New England products and retaining more of the region's wealth within the New England economy; and
- Other related topics.

These technical reports are viewed as "works in progress" because we invite each reader to bring their own contributions to this long term effort of protecting, managing and enhancing New England's forests. The entire set may be viewed at www.newenglandforestry.org. If you have suggested improvements please contact the New England Forestry Foundation to share your thoughts. These technical reports were used as the background to prepare a summary – *New England Forests: The Path to Sustainability*, which was released on June 5, 2014.

If you are not familiar with NEFF's work please visit www.newenglandforestry.org. Not already a member? Please consider joining NEFF – https://41820.thankyou4caring.org.

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The New England Forestry Foundation is a recognized leader in conserving working forests, educating the public about forestry, and assisting landowners in the long-term protection and stewardship of their properties. For almost 70 years, we have demonstrated that well-managed working forests can provide landowners and the community with the prime ingredients for healthy living: clean air and water, sustainable production of an array of forest products, healthy forests for hiking and relaxation, a diversity of wildlife and habitats, periodic income, and renewable natural resources that help support rural economies.

Our Mission is to conserve New England's working forests through conservation and ecologically sound management of privately owned forestlands in New England, throughout the Americas and beyond.

This mission encompasses:

- Educating landowners, foresters, forest products industries, and the general public about the benefits of forest stewardship and multi-generational forestland planning.
- Permanently protecting forests through gifts and acquisitions of land for the benefit of future generations.
- Actively managing Foundation lands as demonstration and educational forests.
- Conservation, through sustainable yield forestry, of a working landscape that supports economic welfare and quality of life.
- Supporting the development and implementation of forest policy and forest practices that encourage and sustain private ownership.


THE PATH TO
SUSTAINABILITY
KEEP NEW ENGLAND FORESTED
Conserve 90% of New England's existing forests
GIVE WILDLIFE HOMES
Provide critical habitat for 338 diverse species
PROVIDE MORE RECREATION
Contribute more than $5 billion to the New England economy
GROW AS MUCH AS WE USE
Meet our consumption with wood from local forests
YOU ARE HERE
SUSTAINABILITY
PROTECT US FROM CLIMATE CHANGE
Reduce extent and impacts of heat waves, floods, and drought
CLEAN & COOL THE AIR
Save $700 million per year in health costs and crop losses
REDUCE USE OF FOREIGN OIL
Displace $1.85 billion of oil annually with wood heat
GROW MORE WOOD
Enhance quality and double wood production
PURIFY OUR WATER
Save $6 billion in water treatment costs
PROVIDE MORE WOOD FOR BUILDINGS
Save 3.5 million metric tons of carbon
CULTIVATE NEW BUSINESSES
Create new cottage industries using non-timber resources
CREATE LOCAL JOBS
Retain 30k jobs and increase exports to more than $10 billion.
New England's forests have tremendous potential to provide economic, environmental, and social benefits to the citizens of the region. Right now, we're letting some of that potential slip away. Through 12 new research reports, New England Forestry Foundation has defined the benefits our region's forests could provide, and those benefits are summarized here along the Path to Sustainability, starting with the premise that we Keep New England Forested.
NEW ENGLAND FORESTRY FOUNDATION

TABLE OF CONTENTS

CLEAN AND COOL THE AIR: Forest Influence on Air Quality in New England: Present and Potential Value

Prepared by Aaron Paul

Part of a larger project on the potential of New England's forest lands coordinated by R. Alec Giffen for the New England Forestry Foundation. Component parts include the following of the larger effort:

1. KEEP NEW ENGLAND FORESTED: Assessing the Current Conservation Status of New England's Forests by Jerry A Bley
2. GIVE WILDLIFE HOMES: Potential of New England's Working Forests as Wildlife Habitat by Jerry A. Bley
3. PROVIDE MORE RECREATION: Forest Recreation Trends and Opportunities in New England: Implications for Recreationists, Outdoor Recreation Businesses, Forest Land Owners and Policy Makers by Craig Ten Broeck and Aaron Paul
4. PROTECT US FROM CLIMATE CHANGE by R. Alec Giffen and Frank Lowenstein
5. CLEAN AND COOL THE AIR: Forest Influence on Air Quality in New England: Present and Potential Value by Aaron Paul
6. PURIFY OUR WATER: The Potential for Clean Water from New England Forests by Aaron Paul
7. GROW MORE WOOD: The Potential of New England's Working Forests to Produce Wood by R. Alec Giffen, Craig Ten Broeck and Lloyd Irland
8. CREATE LOCAL JOBS: Vision for New England's Wood-Based Industries in 2060 by Innovative Natural Resource Solutions, LLC and The Irland Group
9. CULTIVATE NEW BUSINESSES: New England's Nontimber Forest Products: Practices and Prospects by Craig Ten Broeck
10. PROVIDE MORE WOOD FOR BUILDINGS: The Greenhouse Gas Benefits of Substituting Wood for Other Construction Materials in New England by Ann Gosline
11. REDUCE USE OF FOREIGN OIL: The Potential for Wood to Displace Fossil Fuels in New England by Innovative Natural Resource Solutions, LLC
12. GROW AS MUCH AS WE USE: Production versus Consumption of Wood Products in New England by Craig Ten Broeck

A. Overview

New England's states are some of the healthiest in the nation. The United Health Foundation (2012) counts five New England states among the ten healthiest in the country. There are many reasons for this trend. We have some of the lowest rates of obesity, smoking, diabetes, and child poverty in the country, as well as some of the highest concentrations of doctors, rates of exercise and rates of childhood inoculations (UHF 2012). However, in some areas air quality can detract from these advantages. Despite the fact that New England's rural counties have some of the best air quality in the country, southern New England faces a number of challenges. The prevailing winds carry particulates from power plants in the Mid-West region of the country northeast to New England. Prevailing winds also bring ozone from offshore inland to coastal communities. This gives the region higher rates of asthma and other respiratory diseases than the US average (CDC 2013a, 2013b).

This is not to say that the region's air quality is deteriorating. Instead it has gradually improved over the last thirty years. While there are a number of technological and regulatory reasons for this trend, the forested landscape is a major asset for maintaining air quality. Forests absorb air pollutants, filter particulate matter, form a rough surface that creates air eddies which trap particulates, and produce cloud forming nuclei that induce precipitation, which removes pollutants from the air. These effects reduce the incidence of most respiratory and heat-related ailments, improve recovery times, and prevent fatalities (Nowak, et al. 2013, USFS 2001). These services also keep airborne pollutant concentrations within levels suitable for agriculture. A significant increase in tropospheric ozone could dramatically reduce crop yields within the region (Heck, et al. 1986)

The absorption, filtration, and precipitation of airborne pollutants have significant economic benefits in terms of improved health and protected agricultural productivity. For example, planting more urban trees would actually reduce respiratory related fatalities by up to ten deaths per year throughout the region. Our forests also absorb excess atmospheric ozone, which can poison crops through oxidation at higher concentrations. Furthermore, in the face of a warming climate a deforested landscape would compromise many of the things that give New England its high quality of life. Without forests, New England would lose much of its natural ability to process hazardous air pollution, and the region's air quality (especially southern New England) would suffer. In high concentrations ozone acts as a powerful oxidant that damages crops. Increased air pollution could increase the incidence of asthma, bronchitis, heart disease and other respiratory ailments in New England by fifty percent or more. Agricultural output could fall by as much as $500 million in a more polluted environment. This ability of forests to improve air quality will only increase in importance as the local food movement gives rise to more New England farms. In aggregate, we estimate the total annual value of the forest's contribution to human health and agricultural productivity to be $700 million. Discounted at the average cost of capital for New England municipalities, the net present value of these benefits is approximately $17.8 billion. .

1. Air Quality in New England

Air quality is highly variable across New England. The US Environmental Protection Agency (EPA) is required under the Clean Air Act to monitor air quality across the nation. It issues standards for six common pollutants: ozone (O3), particulate matter (PM), lead (Pb), nitrogen dioxide (NO2), carbon monoxide (CO) and sulfur dioxide (SO_2). Areas found to have higher than recommended levels of these pollutants are deemed "nonattainment areas," and are legally required to produce plans to mitigate these pollutants. The air throughout New England currently has safe levels of lead, nitrogen dioxide, carbon

monoxide, and sulfur dioxide. Regionally, a few areas fail to meet ozone and particulate matter standards. Locally, concentrations of ozone and particulate matter can exceed safe concentrations. This is especially common in urban areas or close to industrial facilities.

While stratospheric ozone provides the essential service of absorbing cancer-causing ultraviolet radiation, tropospheric or ground level ozone is a pollutant that can harm respiratory function and even damage crop yields. It is formed by the interaction of sunlight and hydrocarbons or nitrogen oxides emitted primarily by car engines and industrial operations (Kampa and Castanas 2008). Concentration of eight hour ozone in Connecticut and Dukes County, Massachusetts exceed the recommended levels. However, their nonattainment is considered "marginal", which is the least severe of the five possible rankings. By contrast, Los Angeles and the San Joaquin Valley in California are rated in "Extreme" nonattainment, representing some of the worst ozone pollution in the country (EPA 2013d).

Particulate matter (also known as particle pollution) is a complex mixture of extremely small particles and atomized liquid droplets. It is made up of a number of components including acids, organic chemicals, metals, and soil or dust particles. The EPA is primarily concerned with particles 10 micrometers in diameter or less, as these can pass through the throat and nose and enter the lungs, which can harm cardio-pulmonary health. They are categorized into two groups: coarse particles, which are between 2.5 and 10 micrometers, and fine inhalable particles, which are smaller than 2.5 micrometers. They are emitted by industrial process, internal combustion engines and power generation (EPA 2013d). Breathing in particulate matter puts the cardio vascular and pulmonary systems under stress, which leads to reduced function. This can contribute to innumerable symptoms including reduced lung capacity, pulmonary inflammation, impaired heart function and even lung cancer. Persistent exposure to high levels of particulate matter puts people at escalated risk for respiratory ailments including asthma, acute bronchitis, strokes, heart attacks and most other forms of cardiovascular disease. Gradual increases in particulate matter concentrations result in a gradual increase in both the overall prevalence of most of these conditions and their severity. In areas with persistent higher concentration of particulate pollution heart attacks are more likely to be fatal, more children are born with asthma and hospital stays for bronchitis patients are longer. Even short-term, local exposure to particulates less than 2.5 micrometers can increase the risk of hospital admission for cardiovascular and respiratory diseases. The health costs of pollution increase in step with greater concentrations of the pollutants (Miller, et al. 2007, Dominici, et al. 2006, Laden, et al. 2006, Pope, et al. 2002, Pope, et al. 2004).

Average concentrations of particulate pollution are well within safe limits for most of the region. During the winter months concentrations jump as cold temperatures trap the emissions from woodstoves, vehicles and power plants near the ground. This means that particulate matter concentrations in New England can shift between three and thirty micrograms per cubic meter at the same site. Still, on average, all of New England is within recommended limits for 2.5 to 10 micrometer particle pollution. For inhalable particles of less than 2.5 micrometers, southwestern Connecticut is the only part of the region where concentrations exceed recommended limits. Levels of these pollutants are well within compliance for the rest of the region (EPA 2013d).

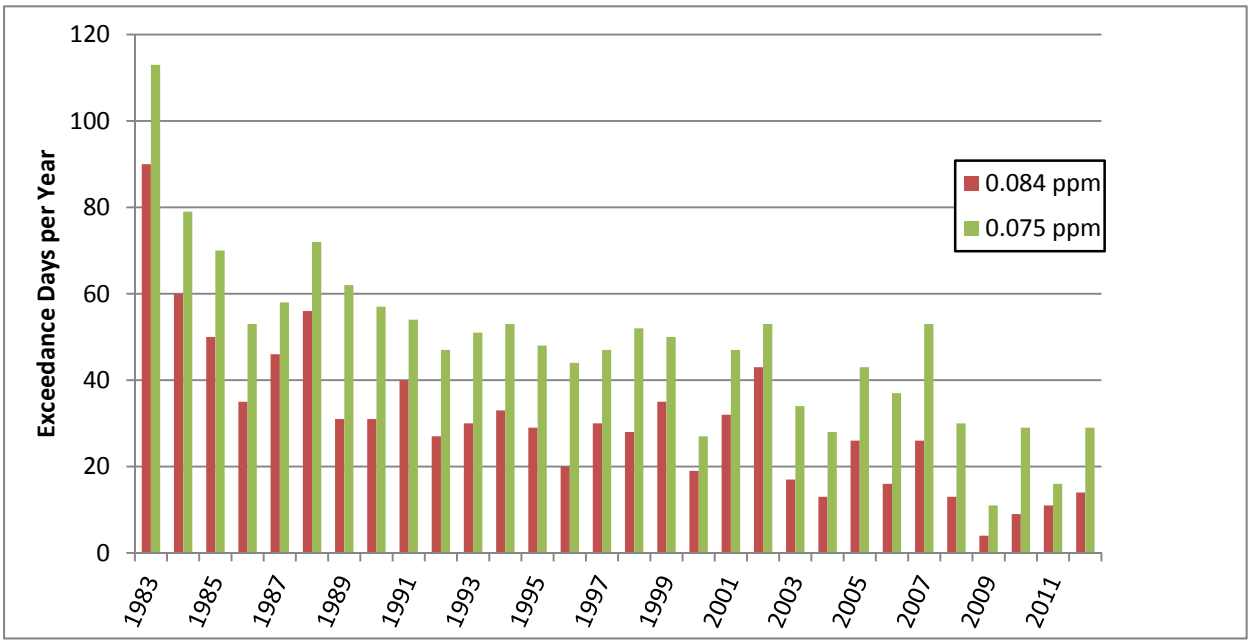
New England's air quality has been steadily improving for the last three decades. Figure 1 shows the total number of nonattainment days for eight-hour ozone pollution throughout the region. A "nonattainment day' in this context is defined as a day in which the air quality monitors in each New England state recorded ozone concentrations exceeding the 1997 eight-hour standard. This does not include days where air quality monitors in only two or three states, for example, exceeded the standard. Since 1983 the number of days each year in which New England's air quality failed to meet eight-hour

ozone standards of 0.084 parts per million, dropped from 90 to 14, while the number of days exceeding the stricter, 0.075 standard dropped from 113 to 29 (EPA 2013a). The EPA standard for the two major air pollutants of concern in New England, the pollutant's sources, the role of the forest in mitigating that pollutant, the health impacts, and the areas of non-attainment are shown in Table 1.

Table 1. Major pollutants of concern in New England

Pollutant	EPA standard	Sources	Role of forests	Health impacts (increased incidence or severity of)	Non-attainment areas and levels
Ozone	0.084 parts per million	• Automobiles • Industrial processes	• Absorption • Filtration • Promoting Precipitation	• Reduced lung function • Asthma • Premature mortality	• All of Connecticut – Marginal • Dukes County, MA – Marginal
PM 2.5	12 micrograms per cubic meter ($\mu g/m^3$)	• Power plants • Construction sites • Industrial processes • Automobiles	• Absorption • Filtration • Surface roughening • Promoting Precipitation	• Bronchitis • Heart Attack • Asthma • Cardiovascular Disease	• Fairfield County Connecticut • New Haven County, CT

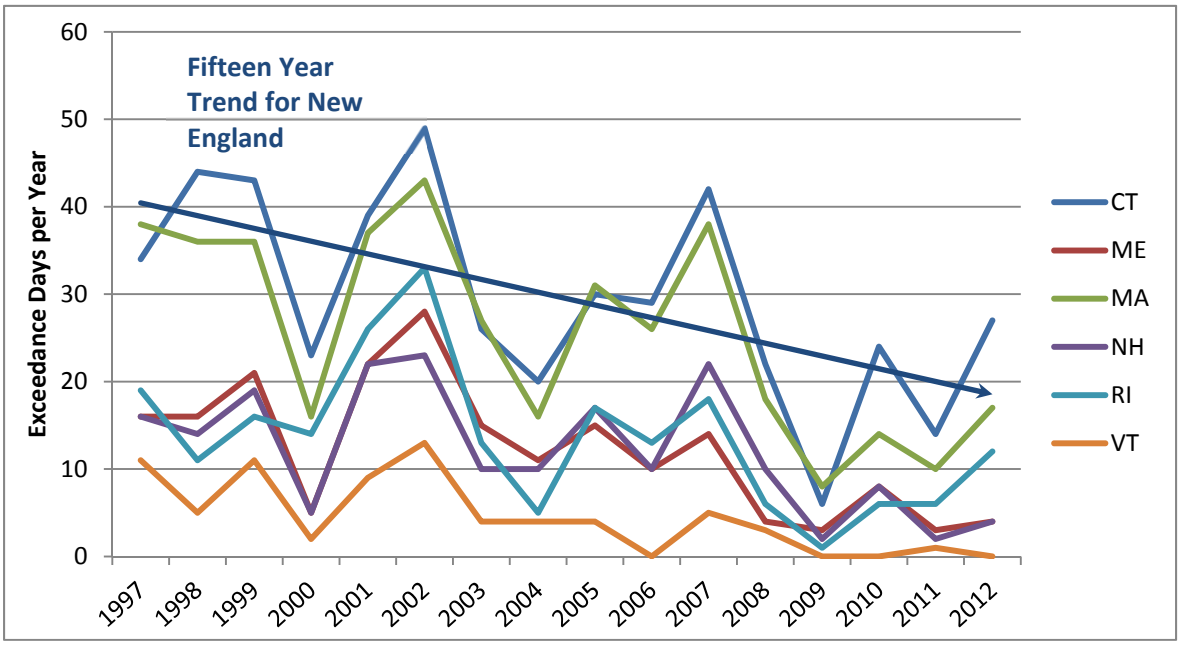
Figure 1. Eight-hour ozone nonattainment days per year in New England for concentrations of 0.084 and 0.075 ppm



Source: US EPA (2013a).

The same trend is apparent at the state level during the past fifteen years. There has been some variation to the decline among states but the overall trend is clear across all states. The more populous and more urban states tend to see more nonattainment days than the rural states. Vermont, Maine, New Hampshire and Rhode Island have all experienced years with zero non-attainment days in the past five years.

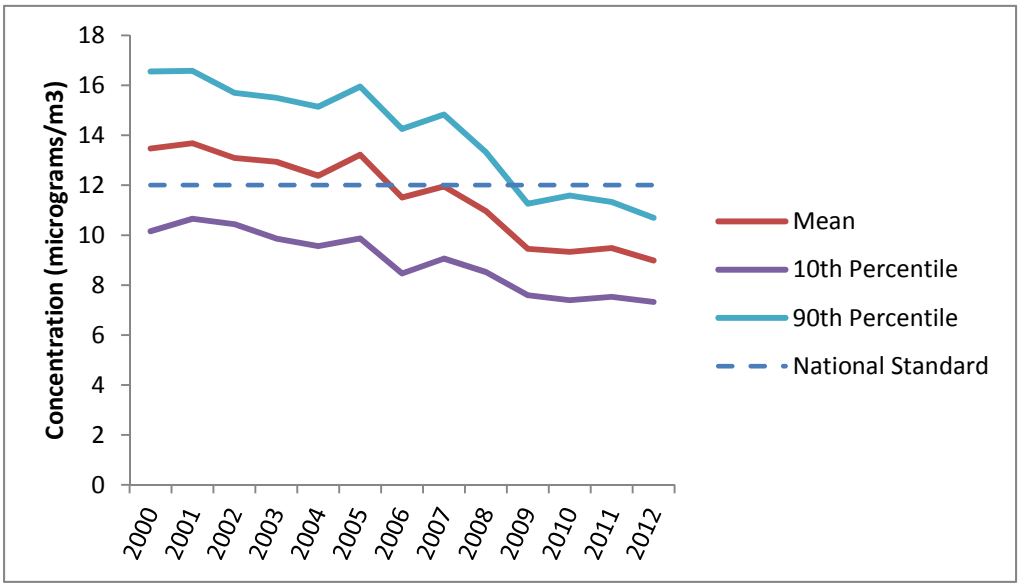
Figure 2. Eight-hour ozone nonattainment days by state per year (0.075 ppm)



Source: US EPA (2013a).

Trends in 2.5 micrometer particulate pollution have been even more positive. In 2000, approximately 60% of the northeast failed to meet the national standard of 12 micrograms per cubic meter. In 2012 more than 90% of the northeast met the standard due to a 33% decrease in PM 2.5 concentrations. Most of the noncompliance was clustered in the tri-state area of New Jersey, New York, and Connecticut (EPA 2013a).

Figure 3. Average annual average PM 2.5 concentrations trends in the Northeast



These positive trends have been achieved in part through regulation of emissions and product innovations, but New England's air quality is not the result of policy alone. The diverse and healthy forested landscape has also contributed to this trend by filtering and absorbing pollutants. The EPA recently considered implementing more stringent restrictions on ozone and particulate emissions. Much of New England would not currently meet the proposed levels (EPA 2013b); however, it is clear that the quality of New England air has improved over the last 30 years.

2. The Role of Forests in Protecting Air Quality

Increased particulate and ozone pollution is associated with increased cardiovascular and respiratory disease, conversely lowering concentrations of these pollutants can reduce mortality (Laden, et al. 2006). Urban trees and forests reduce and mitigate local and regional concentrations of these pollutants by filtering, absorbing, creating eddies in surface winds that trap pollutants, and by contributing to the formation of clouds that cleanse the atmosphere with rain.

Anyone who has sought rest in an urban park notices they are breathing fresher air. This is not just a psychological sensation. Trees also absorb gases in urban environments such as ozone, carbon monoxide and sulfur dioxide. In smoggy cities, such as Los Angeles, pine trees can reduce ozone concentrations by eight percent. In the immediate vicinity of the tree, ozone concentrations can be 50 percent lower than in the ambient air (USFS 2007). Urban forests also help combat the particulate matter that exacerbates asthma and other respiratory conditions. A single mature tree can absorb up to 50 pounds of particulates per year (Dwyer, et al. 1992).

In rural New England, the air quality is by and large exceptional. Rural areas tend to have particulate concentrations three to four times lower than urban areas because there are fewer sources and more filtration and absorption from the surrounding forest (Veira, et al. 2013, Harrison, et al. 2012). The airborne pollutants that do exist are most concentrated near major roads, but these levels decline quickly further from roadways. Old model wood stoves, fire places and certain types of boilers emit a great deal of particulate matter and can be problematic in high and mid density housing environments. The EPA

estimates that if all old woodstoves in the US were replaced with new models it would save an estimated $56-126 billion in health care costs annually from reduced incidence and severity of cardio-pulmonary ailments (EPA 2013c). In low population density environments this is less of a problem and particulate concentrations tend to be very low (USFS 2001).

Forests also help promote cloud cover that increases precipitation, which helps to clean the air of particulates, ozone and other pollutants. Through a complicated process, the forest's biological volatile organic compounds interact with ultra-violet radiation and atmospheric gasses to form cloud condensation nuclei (CCN). These CCN are solid particles typically between one and two micrometers in diameter. Water vapor condenses around them to form droplets which further condense into rain. Airborne pollutants are captured within water droplets and rained out of the atmosphere. Once removed from the surrounding air, particulate matter and ozone no longer pose a threat to human health (Kerminen, et al. 2012). Precipitation is the vector for other forms of pollution, such as acid raid, but overall, rain reduces the concentration of harmful compounds in the atmosphere.

Forests have other climatological effects on the landscape that also promote cloud cover. Forests transpire a great deal of water vapor. This evaporation then condenses in the atmosphere to form clouds. This interplay of condensation and evaporation creates pressure gradients that drive climatic patterns. Air rises over areas with more evaporation, such as forests. Recent research suggests that this creates low pressure that can draw in additional moist air and contribute to cloud cover and additional precipitation in the areas with the highest evaporation. Thus, even modest deforestation can create a more arid environment. Without forest cover this dynamic shifts so that the higher evaporation rates over surface water draws moisture from the land out to sea (Makarieva, et al. 2013, Sheil and Murdiyarso 2009).

The physical form of the forest plays an important role in mitigating air pollution. The tall, aerodynamically rough surfaces of forests cause a change in the momentum of air between terrestrial surfaces and the atmosphere. This allows high deposition rates of pollutant gases and particulates, effectively filtering them from the air. Thus, forests help prevent particulates and ozone from traveling between geographical regions on the wind (Fowler, et al. 1999).

This pollution remediation has direct benefits for human health. A recent US Forest Service study of ten cities is the continental US found that urban forest cover saves lives every year. By absorbing and filtering pollutants from the air, urban trees have the effect of reducing human mortality associated with respiratory illnesses by an average of one individual per city per year. By capturing 12.7 tons of particulates Boston's trees prevent an average of two respiratory illness-related fatalities every year. New York's trees prevent a staggering seven such fatalities annually (Nowak, et al. 2013).

These are the benefits from urban forests alone – imagine what the benefits are from the region's rural and suburban forests.

Humans are hardly the only species that suffer in high ozone environments. Most staple row crops suffer damage when ground-level ozone exceeds its natural ambient range of 45 to 65 parts per billion. At higher concentrations, ozone oxidizes the plant foliage causing it to brown or redden, which can result in necrosis or chlorosis. Corn, wheat and soybeans suffer declines in yields between 20 and 40 percent at higher ozone concentrations (Heck, et al. 1986). Deforestation in New England is not without historical precedent, as New England has been largely deforested farmland in its history. Over 70% of some portions of the region were cleared for agriculture in the 19th century. However, during this period industrial and automotive pollution were not sources of air pollution as they are today, so it is essential

to have forests to help protect agricultural crops from pollutants thereby maintaining agricultural productivity in the region.

These benefits are contingent upon proper management practices. Trees can most effectively absorb vehicle emissions if they are located close to major transportation arteries. The correct trees must be selected to positively impact ozone concentration. In some environments, certain species can actually exacerbate ozone issues through the release of biological volatile organic compounds (BVOCs) (USFS 2007). At a larger scale, landscapes of forests must be preserved to realize the benefits of cloud formation, evapotranspiration and surface roughening.

3. The Clean Air Potential of New England Forests

Forests play a key role in maintaining air quality in New England. However, this benefit could be greater. Improvements in urban forest cover and the maintenance of existing rural forests can help New England reduce the incidence of bronchitis, asthma, heart attacks and other respiratory-related illnesses, while also protecting agricultural yields.

Urban trees prevent approximately $9 million in annual respiratory related illness costs in the city of Boston, which is a per capita benefit of $14.71. Presumably a similar benefit is enjoyed by the 90% of New Englanders who live in urban or suburban areas. This implies a total annual benefit from urban trees of $188 million per year. Most of which is due to reduced mortality from respiratory related illnesses. Other urban areas in the country enjoy as much as $20.66 per capita in health benefits from urban and suburban trees (Nowak, et al. 2013). If New England strategically increased urban and suburban forest cover, and realized this higher per capita benefit, annual avoided respiratory-related healthcare expenses would grow to $265 million. This represents a potential increase of $76 million. Discounted at the average cost of capital for New England municipalities these savings have a net present value of $6 billion.

Agriculture is an important part of the New England identity and a significant industry. In 2007 New England farms sold $2.6 billion worth of products (American Farmland Trust 2010). Our crops are, however, vulnerable to ozone pollution. Research shows that yields and quality fall dramatically once ozone concentrations surpass 65 parts per billion. If this were to happen in New England, yields could easily fall by 20% (Heck at el. 1986). Because of the local climate dynamics an increase in ozone concentration is a real possibility for New England. Ozone rich air blows up the eastern seaboard from the mid-Atlantic to make landfall on our coasts. It routinely brings air with ozone concentrations of 100 parts per billion. Our coastal forests help mitigate the impact of this pollution through filtration and absorption. These processes can reduce concentrations by as much as 70 parts per billion. Without the forests, this reduction would not happen and agricultural yields would suffer in the high ozone environment. A 20% loss in agricultural productivity would mean approximately $520 million in lost revenue. Discounted at the average cost of capital for New England municipalities, this preserved productive capacity has a net present value of $11.8 billion.

Table 2 summarizes the benefits to human health and economic prosperity from forest-provided clean air in New England. Using research and valuations done on the subject, we estimate that forests currently provide approximately $700 million in services annually. If the forest is maintained, the NPV of this benefit would range between $15.3 and $19.0 billion depending on the discount rate applied.

Table 2. Summary of current and potential health and economic benefits of clean air

Benefit	Annual benefit	Estimates of potential NPV			Sources
		Low	Best	High	
Improved human health	188,510,590	5,163,368,508	6,006,367,448	6,444,788,430	Nowak, et al. (2013)
Agricultural productivity	519,447,000	10,125,672,515	11,778,843,537	12,638,613,139	American Farmland Trust (2010); Heck, et al. (1986)
Total	707,957,590	15,289,041,023	17,785,210,986	19,083,401,568	

Table 3. Yields on New England municipal bonds

Discount Rate - Low	4.11%
Discount Rate - Best	4.41%
Discount Rate - High	5.13%

Source: Moody's (2013).

Table 3 lists the discount rates used to discount future benefits. They represent a range of yields on municipal bonds issued by New England states and municipalities. These bonds are overwhelmingly investment grade, which gives New England a low cost of capital. The best discount rate is the median yield on New England 20-year bonds issued over the last six months (Moody's 2013). Discounting the annual benefit of $700 million at this rate gives a NPV of $17.8 billion.

It is always difficult to quantify the value of an ecosystem service. It is especially difficult in this case because the forest is only one factor in providing clean air. Air quality is affected by consumer choice, industrial emissions, regulations and climactic influences, as well as forests. To isolate the present and future value of the contribution of forests requires many assumptions that are open to debate. That being said, this exercise shows that the annual benefit of our forests to human health and economic productivity is in billions of dollars.

B. Conclusion

Without forests and urban trees, New England would be a hotter, more arid, smoggier and less healthy environment. The population would experience more fatalities and hospitalizations from respiratory ailments. Productivity would suffer. Increased ozone and particulate matter concentrations would increase the prevalence of asthma, bronchitis, heart disease, heart attacks and other respiratory related illnesses. Greater prevalence of these conditions would lead to higher mortality. Forests also play a role in forming clouds and creating precipitation. Because rain removes pollutants from the air, a more arid environment would also be more polluted. Agriculture would suffer reduced yields from the effects of increased ozone concentrations. Maintaining our forests will save New Englanders nearly $700 million in lost agricultural productivity and healthcare costs annually. The NPV of these benefits is $17.8 billion when discounted at the median cost of capital for New England municipalities. This is the first attempt to estimate the economic value of the forest's contribution to air quality throughout New England.

Usually studies are much more localized and value only one or two services. This leaves margin for error in our estimates, but it would be difficult to challenge the claim that the value of air quality benefits of New England's forests are in the billions. The CDC estimates that asthma alone costs Americans $54 billion annually. The annual cost of heart disease, including heart attacks, is estimated to be almost $500 billion (CDC 2013a, 2013b). Air quality and its impacts on health and productivity are major concerns in New England. While our air has improved over the past few decades, it can continue to improve. Forests can play a key role in this process by filtering and absorbing pollutants from the atmosphere, by creating a rougher surface that captures pollutants and by enhancing rainfall. These are extremely valuable services that reinforce the region's healthy identity.

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