



HARVARD FOREST

Harvard University

► **2015-2016** Biennial Report

The Harvard Forest, founded in 1907 and located in Petersham, Massachusetts, is Harvard University's 4,000-acre center for ecological research and education, engaging thousands of students and hundreds of scientists each year. Interdisciplinary scholars are drawn from Harvard and an international array of colleges and universities, as well as regional conservation organizations, forestry groups, and K-12 classrooms. The Forest has served as the Northeast regional center for the Department of Energy's National Institutes of Global Environmental Change (NIGEC; 1988), the National Science Foundation's Long-Term Ecological Research (LTER; since 1988) and National Ecological Observatory Network (NEON; since 2011) programs, and the Smithsonian Institution's Global Earth Observatory (ForestGEO; since 2010). Thousands of Harvard Forest research publications and datasets, some dating back to the Forest's founding, are publicly available online.

The Harvard Forest landscape, comprised of varied forests, pastures, wetlands, and streams, is one of the oldest and most intensively studied research landscapes in North America. Open to the public year-round, the site includes educational and research facilities, the Fisher Museum, and miles of recreational trails.

SUPPORT

The Harvard Forest is a department of the Faculty of Arts and Sciences (FAS) of Harvard University. In the 2015 fiscal year, a total operating budget of \$5.4 million was funded nearly evenly by research grants and restricted endowments and gifts.

Research and education at the Forest are supported by many sources, public and private. Wherever possible, those funding sources have been noted throughout this report.

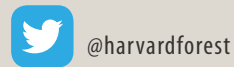
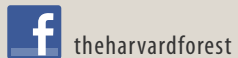
To support the research, education, and conservation activities described in the report, please get in touch. We welcome partners in this work.

CONTACT

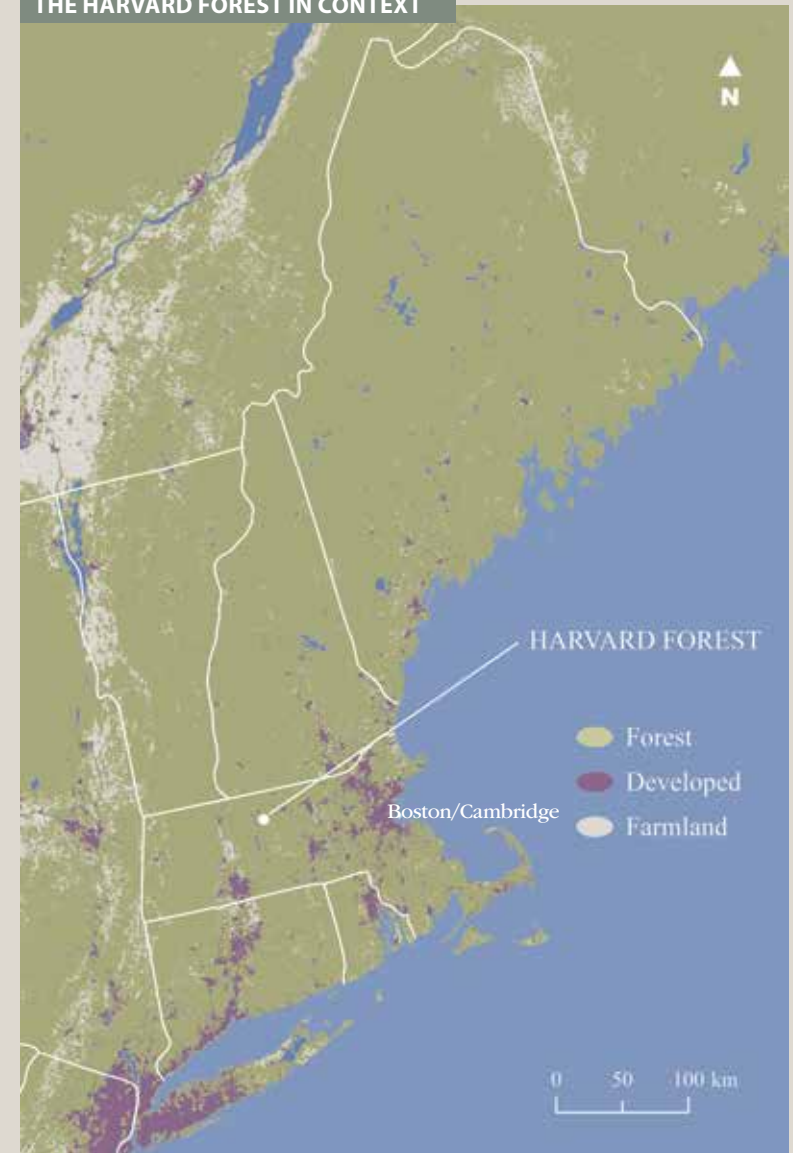
HARVARD FOREST
Harvard University

324 North Main Street
Petersham, MA 01366
(978) 724-3302
HFoutreach@fas.harvard.edu

<http://harvardforest.fas.harvard.edu>



THE HARVARD FOREST IN CONTEXT



Cover image: Harvard Forest Summer Research Program student Roxanne Hoorn examines an ant on Prospect Hill.



Friends and colleagues:

Ten years ago I challenged the community at the Harvard Forest to develop a diagram to represent our relationship with the rest of Harvard University. Rather than depicting us as a satellite positioned 65 miles distant from Cambridge, the group chose to represent the Forest as a central hub of the university, interconnected through students, faculty, and other colleagues across the physical, social, and biological sciences, design, engineering, law, public health, policy, and even the arts and humanities.

That spirit of centrality and ecological connectedness comes through vividly in this report highlighting our 110th year. The Harvard Forest is a unique institution — a year-round and fully staffed department distant from but thriving in its collaborations across Harvard and with colleagues across New England, the country, and the globe.

We invite you to join us in these endeavors.

David R. Foster
Director

OUR IMPACT AT A GLANCE

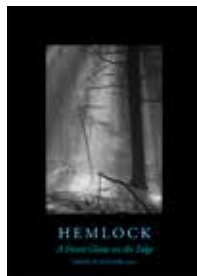
From fall 2014 to spring 2016, Harvard Forest scientists and students published over 75 peer-reviewed articles in journals including *Nature Climate Change*, *Proceedings of the National Academy of Sciences*, *Global Change Biology*, *Ecological Monographs*, and the *Journal of Ecology*.

These publications were featured in more than 100 media stories, including features in the *New York Times*, *Washington Post*, *Boston Globe*, *National Geographic*, *USA Today*, *Climate Wire*, *BBC*, *New England Public Radio*, *Harvard Gazette*, *Orion*, *Smithsonian*, *Christian Science Monitor*, *National Science Foundation's Science 360*, the Associated Press, and many other regional, national, and global outlets.

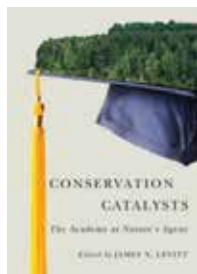
PUBLICATION HIGHLIGHTS

- » Keenan et al. 2014. Net carbon uptake has increased through warming-induced changes in temperate forest phenology. *Nature Climate Change*.
- » Blumstein and Thompson. 2015. Land-use impacts on the quantity and configuration of ecosystem service provisioning in Massachusetts, USA. *Journal of Applied Ecology*.
- » Crowther et al. 2015. Biotic interactions mediate soil microbial feedbacks to climate change. *Proceedings of the National Academy of Sciences*.
- » Driscoll et al. 2015. US power plant carbon standards and clean air and health co-benefits. *Nature Climate Change*.
- » Buckley et al. 2016. Using codisersion analysis to quantify and understand spatial patterns in species-environment relationships. *New Phytologist*.
- » Lovett et al. 2016. Nonnative forest insects and pathogens in the United States: Impacts and policy options. *Ecological Applications*.

BOOKS AND REPORTS



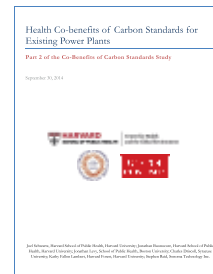
Hemlock: A Forest Giant on the Edge.
By David Foster, Ben Baiser, Audrey Barker Plotkin, Anthony D'Amato, Aaron Ellison, David Orwig, Wyatt Oswald, Jonathan Thompson. 2014. Yale University Press, New Haven, CT.



Conservation Catalysts: The Academy as Nature's Agent.
Edited by James Levitt. 2014. Lincoln Institute of Land Policy, Cambridge, MA.



Wildlands and Woodlands Stewardship Science: Manual for Long-Term Forest Monitoring.
By Edward Faison, David Orwig, David Foster, Emily Silver, Brian Hall, Brian Donahue, Audrey Barker Plotkin. 2014. Highstead Foundation, Redding, CT.



Co-benefits of Carbon Standards.
Part 1: Air Pollution Changes under Different 111d Options for Existing Power Plants
Part 2: Health Co-Benefits of Carbon Pollution Standards for Existing Power Plants.
By Charles Driscoll, Jonathan Buonocore, Habibollah Fakhraei, Kathy Fallon Lambert. 2014.





THE FOREST'S NEW FRONTIER: Harvard Farm

Until recently, the Harvard Forest was, like most of central New England, a landscape of maturing trees. A small cow pasture beside the Fisher Museum showcased the land's agricultural past.

Over the past decade, we have added nearly 100 acres of open land to the Forest, first through the acquisition of the Bryant Farm in 2008, and an additional 70 acres in 2013.

The Petersham Country Club, as the 70-acre parcel was formerly known, had been managed for nearly a century as a golf course with a pedigree, designed by renowned landscape architect Donald Ross. Without regular mowing, in 2013 the land quickly became an unkept grassland.

Recognizing the importance of open land both for biodiversity and local food production, director David Foster and the Harvard Forest Woods Crew — with input from a team of scientists, conservation groups, and farmers — initiated a project to study plant, soil, water, and wildlife dynamics in a working landscape where cattle graze, trees are harvested, and hay is cut after nesting season. Within two years, bobolinks were nesting in overgrown fairways and American woodcocks were emerging from the adjoining brushlands.

The Woods Crew fenced the property, and local farmers now graze nearly two dozen cattle, following two experimental grazing methods: intensive traditional and light rotational. On the southern half of the property, the Crew cut hay in late summer 2014 and 2015.

An array of 10-by-10-meter long-term study plots now tracks changes in vegetation and soil carbon and nutrients in the former fairways, putting greens, and recently harvested areas.

Longtime Harvard Forest research collaborator Glenn Motzkin inventoried the plants in the plots in 2014, identifying 364 species — 31 not previously documented at the Harvard Forest — bringing the total vascular plant species count at Harvard Forest to 840.

Forty percent of the plants Motzkin identified at the Farm were not native to New England.

In summer 2015, undergraduate students in the Forest's Summer Research Program began to extend the analyses of the Farm's plant community. A student team led by ecologists Dan Flynn of the Arnold Arboretum and Martha Hoopes of Mount Holyoke College is now investigating how grazing intensity drives biodiversity, ecosystem services, and plant invasion.

Scientists from the University of New Hampshire, led by ecologist Serita Frey, are studying long-term changes in soil carbon stocks across the management zones.

◀ Today, cattle graze former greens and fairways.



364 Plant species
identified
on the Farm 

"In the heavily-forested landscape of central New England, agricultural lands provide critical habitat for a wide range of species, including numerous species of conservation concern."

— Glenn Motzkin, from his 2014 report, "Biodiversity Conservation on Agricultural Land"



**BOX 1. WORKING LANDSCAPES:
RESEARCH TOWARD A SUSTAINABLE FUTURE**

The Harvard Farm has been named a signature landscape for the new Sustainable Working Landscapes initiative based at the Harvard Forest and led by Brian Donahue, an environmental historian at Brandeis University, working with HF Director David Foster and new research assistant Jay Aylward. The Farm and other demonstration sites across New England will combine integrated landscape management (sustainable farming and forestry) with long-term studies on water quality, carbon emissions, wildlife, and biodiversity. The team's case studies, peer-reviewed publications, research protocols, and educational materials will help advance sustainable management practices among conservation groups, landowners, and communities.

Top: A former putting green transitions to grassland in the first year of the project.



HF Summer Research Program student Brittany Cavazos surveys the Farm's plant communities with research mentor Martha Hoopes.



Twenty-seven 10-by-10-meter long-term study plots now track changes in vegetation and soil carbon and nutrients in former fairways, putting greens, and recently harvested areas.

25 Number of cows grazing Harvard Forest property in 2015



Funding Sources:





HEMLOCK: A Forest Giant on the Edge

Just as lush swaths of eastern hemlock trees have flourished across the eastern forests of North America, so too has hemlock woven itself into the fabric of research and education at the Harvard Forest.

A 2014 book co-authored by seven Harvard Forest scientists, *Hemlock: A Forest Giant on the Edge* (Yale U. Press), recounts the diverse roles hemlock has played in science and culture, the many ways we study hemlock today, and hemlock's place as a cornerstone of early Harvard Forest research.

In 1927, Bob Marshall, who would go on to a career with the Forest Service and to found the Wilderness Society, collaborated with HF's founding Director Richard Fisher on a painstakingly detailed study of hemlock and its ability to survive shade, wind, and repeated harvesting.

Today, Harvard undergraduates, K-12 students, and other tour groups return to the Bob Marshall plot to take field measurements and discuss how hemlocks continue to shape the landscape over time.

Since 2012, the eastern hemlocks on the Forest's Prospect Hill tract have been in steady decline due to the invasive insect pest, the hemlock woolly adelgid. The adelgid has killed millions of trees since its introduction to the U.S. from Japan in the early 1950s, and is now steadily marching north into Maine.

Seeing the thinning needles on our hemlocks, visitors often ask, what are you doing to save the trees? Chemical intervention is not viable at the forest level, so we're doing the next best thing: studying the forest in meticulous detail, to build the knowledge base for future pest control and prevention — and to document the sweeping transition as a new generation of trees (oftentimes black birch) moves in.

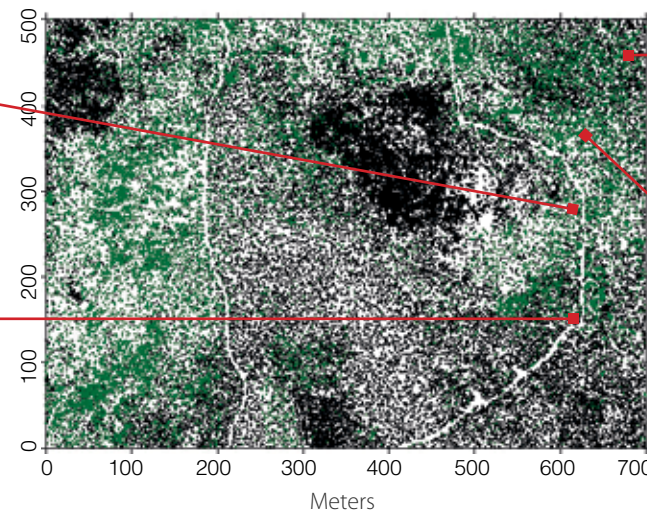
Documenting a Time of Change: 25,804 individual hemlock trees are shown here in green, with other woody species in black, inside the 85-acre (35-hectare) Harvard ForestGEO plot on Prospect Hill. Inside this study block, all stems greater than 1cm in diameter (116,226 stems) are mapped, tagged, and measured every 5 years. With support from the Long-Term Ecological Research Program (see page 12), we are able to study the changing forest dynamic from many angles. Most of the measurements on Prospect Hill have been taken continuously since the 1990s; others were launched more recently to capture the story of hemlock loss and forest regeneration.



Soil: Shifting microbial communities & biogeochemistry



Pollen: Historical loss of hemlock (c. 5500 years ago) revealed by analysis of buried pollen



Water: Changes in stream flow and carbon release to the Quabbin Reservoir and Miller's River



Air: Carbon storage by growing trees; carbon loss from soils and decomposing wood

A red eft below the shady hemlocks at Harvard Forest's Pisgah tract.

"It's hard to imagine our woods and stream banks without their deep shade, or spring without the songs of black-throated green warblers... or the brilliant orange flash of a Blackburnian warbler high in the canopy."

— Rob Bryan, from a review of *Hemlock* in *Northern Woodlands*



BOX 2. SCIENCE POLICY EXCHANGE: TACKLING PESTS BEFORE THEY INVADE

Invasive pests like the hemlock woolly adelgid pose one of the greatest threats to forests and urban street trees today. Like many pests, the adelgid was unintentionally introduced to the U.S. via global trade.

In 2014, the Science Policy Exchange, led by Kathy Fallon Lambert, HF's Director of Science & Policy Integration, convened top scientists and policy experts to assemble the most comprehensive paper available on the forest pest problem, its ecological and economic impacts, and potential policy solutions. Their synthesis, led by Gary Lovett at the Cary Institute of Ecosystem Studies and published in the journal *Ecological Applications* in May 2016, shows that instead of reacting to pests once they arrive, preventing the arrival of future pests holds the greatest promise for safeguarding our nation's forests and community trees.

The Exchange is now working with journalists to increase awareness of trade as the source of damaging forest pests, and working with policymakers and business leaders to change trade policies and protocols.



Top: Students from Holyoke Catholic High School in Springfield, Mass., measure changes in hemlock growth as part of the HF Schoolyard Ecology Program.

Above: The Forest Pests and Pathogens working group first convened at the Cary Institute of Ecosystem Studies in 2014.



Dying hemlocks on Prospect Hill are being replaced by young black birch saplings.

Funding Sources:



SPE Pests and Pathogens project: Doris Duke Charitable Foundation, the F.M. Kirby Foundation, and the Northeastern States Research Cooperative of the USDA Forest Service

Timber products are one of the many vital forest services analyzed and mapped by the Landscape Futures project.



MAPPING THE FUTURE

It's the year 2065. You're standing on a mountaintop. What do you see?

In 2015, natural resource and conservation professionals, business owners, government officials, and family forest owners came together to discuss the likely answers to this question. Their responses, compiled separately in workshops in each New England state, will help form the basis of the New England Landscape Futures Project, co-led by Harvard Forest Senior Ecologist Jonathan Thompson and HF Director of Science and Policy Integration Kathy Fallon Lambert.

Over the next two years, Harvard Forest scientists will use the scenarios developed by the Landscape Futures Project to create a high-powered landscape simulation model.

The model will create several “what if...” maps of New England's future, projecting 50 years of forest harvest, agriculture, conservation, and land conversion for development. Trees will grow, agriculture will unfold, and development will clear trees for buildings and roads in fine-scale resolution, based on meticulous research about how these processes work.

The maps will reveal the consequences of millions of individual land-use decisions that make up each scenario, including many decisions being considered in board rooms and living rooms across New England today.

Experience shows us what a powerful tool these maps can be.

The *Changes to the Land* project for Massachusetts, led by Thompson and Lambert in 2013, mapped the impacts of four potential futures on flood protection, climate mitigation, forest composition and wood supply, and wildlife habitat.

The project was released in December 2013 to widespread media coverage and public interest. Since then, Lambert and Thompson have continued the project's momentum across the state, giving thirteen presentations in 2015. The report has been used and adapted by many land trusts and conservation organizations, as well as the Mass. Department of Energy and Environmental Affairs.

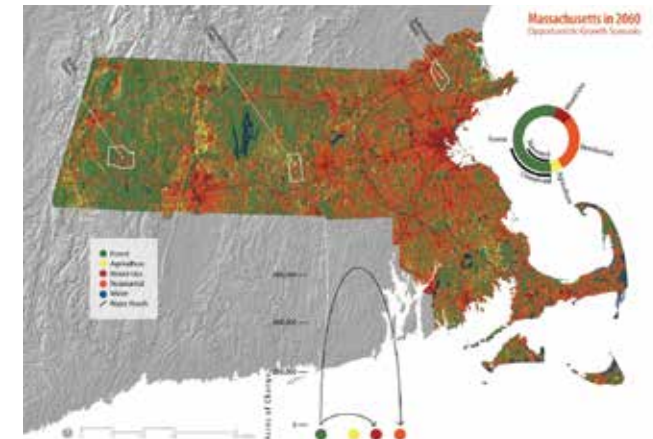


Massachusetts stakeholders met with Thompson and Lambert to discuss the future landscape scenarios in 2013.

HARVARDgazette

Why More 'Hotspots' Aren't So Cool
Harvard study maps out hardest-working areas where ecosystems are doing more with less

Full news article  Scientific paper 
Shawcross M. and Thompson J. 2015. *Journal of Applied Ecology*.



Massachusetts in 2060 under the Opportunistic Growth scenario (from *Changes to the Land*).

“The retreat of the forests does more than threaten the state’s natural beauty; forests provide habitat for wildlife, suck carbon out of the atmosphere, and create economic opportunities for forest products that would be lost if the trees vanish.” — editorial in *The Boston Globe*, following the release of *Changes to the Land*

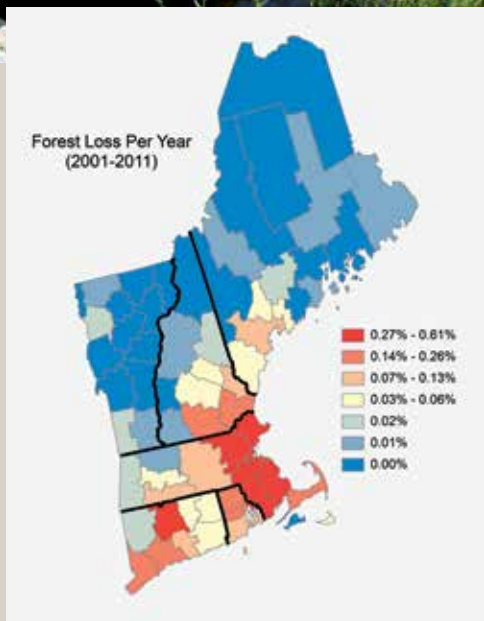


BOX 3: TRACKING RECENT TRENDS

HF Senior Ecologist Jonathan Thompson specializes in models that look to the future, but to accomplish this, he must start by documenting land-use changes in the past.

His research team's analysis of land-use trends over recent decades has revealed important insights about the state of land development, timber harvesting, agriculture, and land conservation in each New England state, and in the region as a whole. For example, he found that from 2001 to 2011, an average of 11,500 acres was lost to development in New England each year. More than half of this occurred in Massachusetts, driven by the sprawling expansion of developed areas. On the other hand, over 190,000 acres have been protected from future development annually through efforts by conservation groups and agencies. Over the coming century, the rate of forest loss in New England is expected to have an even greater impact on ecosystem services than climate change.

From 2001 to 2011, an average of 11,500 acres was lost to development in New England each year. ►



A view from the Holyoke Range in Massachusetts.

Funding Sources:





LOOKING BACK TO LOOK FORWARD

In many ways it's a good time to be a tree on the east coast — especially when it comes to summer rainfall. Today's Northeastern forests are growing in one of the wettest periods of the last 500 years.

But even in the humid Northeast, severe droughts do occur, and according to research by HF Senior Ecologist Neil Pederson, these droughts can be significant architects of forest change.

In the Forest's newly refurbished Tree Ring Laboratory, led by Pederson with HF Forest Ecologist Dave Orwig, students and researchers can pinpoint the periods when trees faltered due to a lack of resources (caused by drought, shade, pests or disease) by looking at tree ring samples from individual trees.

In tough years, a tree's annual growth rings bunch tightly together. When the stress on the tree is released — say, when a neighboring tree dies and allows in a flood of new light — the rings spread out, reflecting more annual growth in the tree.

Historical accounts, plus a growing database of ring records from thousands of trees, help the Tree Ring team assign specific causes to these boom and bust periods.

As the tree ring record grows, so too does the team's ability to see how forests have changed over time and space.

During the American Revolution, across an area spanning 300,000 miles in the southeastern U.S., the simultaneous death of many trees opened bright gaps in the forest — prompting a new generation of saplings to grow in the light (with widely spaced growth rings).

There's no historical evidence that those dead trees succumbed to logging, ice storms, or hurricanes. Instead, they were likely weakened by repeated and intense drought, followed by a devastating late-season frost that, until Pederson studied the trees, was buried in historical diaries like Thomas Jefferson's *Garden Book*, far from the body of scientific literature. In May 1774, Jefferson recounted "a frost which destroyed almost every thing" at Monticello, that was "equally destructive thro the whole country and the neighboring colonies."

The oversized generation of new trees that followed the 1774 frost — something like a baby boom — shaped the old-growth forests that still stand in the Southeast today.

Droughts affect the Northeast, as well. A 6-year drought in the 1960s and a 23-year drought in the 1500s appear in the tree rings as a synchronous and abrupt decline in tree growth across the Hudson Valley.

When the landscape experiences a shifting water table, some tree species win, and others lose. Maple, birch, and tulip poplar grow best — and also worst — in precipitation extremes. Oak is more steady throughout the changes.

At a millennial time-scale, the story deepens.

In a project called the Paleo-Ecological Observatory Network (or PaleON), 2016 Harvard Forest Bullard Fellow Jason McLachlan (see back inside cover), has convened more than 100 scientists, including Pederson, to reconstruct the past 2,000 years of forest change in the Northeast. To hone computer models, the PaleON team uses the best known data: tree ring records, plus colonial land surveys and meticulous ecological histories of fire, human influence, shifting water bodies — and especially the fossil records of mud, charcoal, amoeba, and pollen from the bottoms of hundreds of wetlands and ponds.

Their findings will help build simulation models that operate like real forests do, responding to wet and dry periods, pest outbreaks, fire, human influence, and extreme storm events.

Informed by paleo history and tree rings, these simulation models will help us learn more about our past, and in doing so, give us clearer insight into our future.

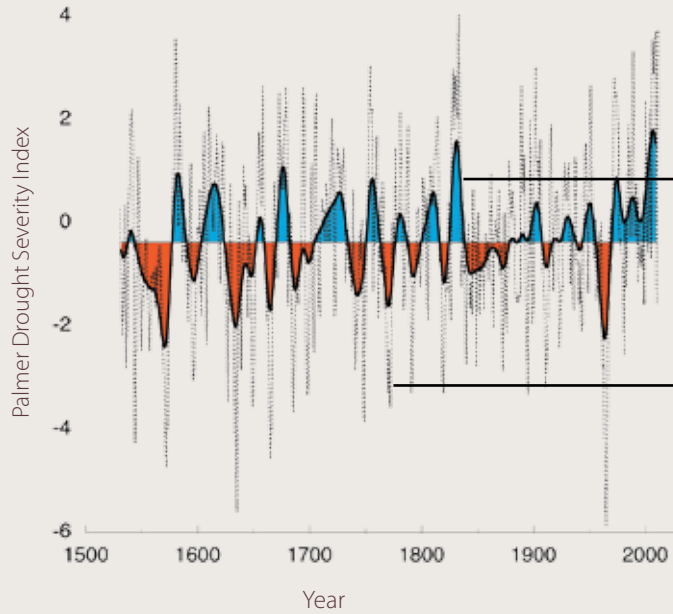


Ancient oaks in Old Maids' Woods City Preserve, one of Pederson's study sites in New York.

"This data is like a snapshot of what was there right before the axe and plow came."

— Jason McLachlan, HF Bullard Fellow, as told to *The Atlantic*

500 YEARS OF HUDSON VALLEY DROUGHT



1830s: Wide rings reflect a wet period across much of the Eastern U.S.

1770s: Narrow rings reflect drought followed by late frost in the Southeastern U.S.

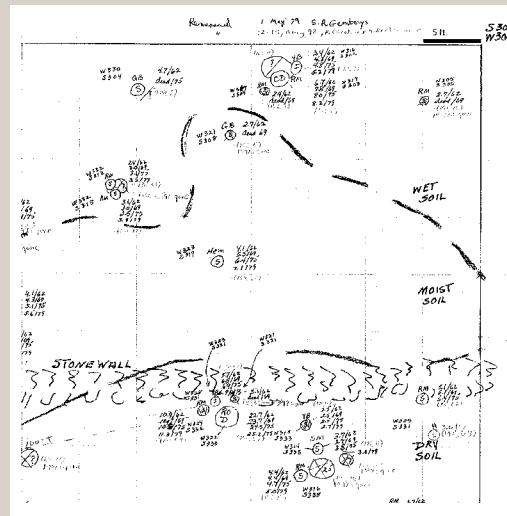
Cross-section of a chestnut oak from Lilley Cornett Woods in Kentucky.

BOX 4: LAND OVER THE LONG-TERM

The Lyford Plot is one of the Forest's signature long-term datasets: a meticulous, four-decade record of the growth of more than 6,000 individual trees across seven acres of mixed deciduous forest. Today this forest is about 110 years old, and analysis by HF senior ecologist Audrey Barker Plotkin shows that the trees have grown steadily over time. Biomass accumulation has not yet leveled off. The plot has been re-measured four times since the initial census by soil scientist Walter Lyford in 1969, with help from several Summer Research Program students. Barker Plotkin's team is planning the next census for the plot's 50th anniversary in 2019.



HF Summer Research Program students Collette Yee and Kate Eisen measure Lyford Plot trees with mentor Audrey Barker Plotkin.



Walter Lyford's original 1969 map includes details on living and dead trees, as well as cultural artifacts, soils, and large stones.

HF Summer Research Program student Megan Shadley pulls a sediment core from Little Pond with mentors Wyatt Oswald and Elaine Doughty.



Funding Sources:



Bullard Fellow Joshua Rapp counts sugar maple seeds in the canopy on Prospect Hill Road.



SUGAR MAPLES IN THE SPOTLIGHT

For centuries, maple syrup producers have eyed the weather to explain spring sugar yields. Weather affects how much sap flows out of the tap, but research by Bullard Fellow Joshua Rapp (see back inside cover) shows that sap flow is only one piece of the sugaring puzzle.

Another key determinant is the concentration of sugar in the sap. Sugar maple sap is typically two to three percent sugar, but some years, the sap runs sweeter, allowing for more syrup yield and profit. Weather may explain sap flow, but alone, it is a surprisingly bad predictor of how sweet the sap will be in any given year.

Rapp's recent analysis of 17 years of syrup production at 28 sites in Vermont revealed that the best predictor of sap sweetness is found in the tree's seed crop the year before.

Both seeds and sugar are made from carbohydrates produced and stored in the tree. If a sugar maple produces a bumper crop of seeds one summer, called a mast seed year, then the following spring, its stores are low for making sugar.

Rapp's research shows that in Vermont, syrup production declined following every mast seed year. In sugar maples, mast seeding tends to occur every two to five years. The most recent mast year occurred in 2011.

Because seeds develop a full six months before syrup harvest, Rapp hopes his research can help syrup producers plan ahead.

Rapp has been analyzing seeds and sugar production in the sugar maples at Harvard Forest since 2012. The sap sugar content of HF maples has risen every year, and Rapp expects it to rise until the next masting year.

Spring 2015, which began three weeks later than usual, was the second highest yielding syrup year yet — with more than a dozen gallons of sap boiled down at the Harvard Forest sugar house. And the HF staff can attest, experimental syrup tastes plenty sweet.



Harvard Freshman Seminar student Anneli Tostar taps a sugar maple with Joshua Rapp.



**Gallons of
maple syrup
made from
HF sap in 2015**

The New York Times



The Bloom Is On for Maple Syrup

Study links high syrup years with low seed years

Full news article

Scientific paper

Rapp J. and Crone E.
2015. Forest Ecology
and Management.



Funding Sources:



HEATING LOCALLY AND SUSTAINABLY

In winter 2014, the five main buildings on the Harvard Forest campus got a little warmer and a lot more sustainable. The buildings are now heated by a highly efficient thermal biomass system that runs entirely on wood sustainably harvested from our own land by the Harvard Forest Woods Crew.

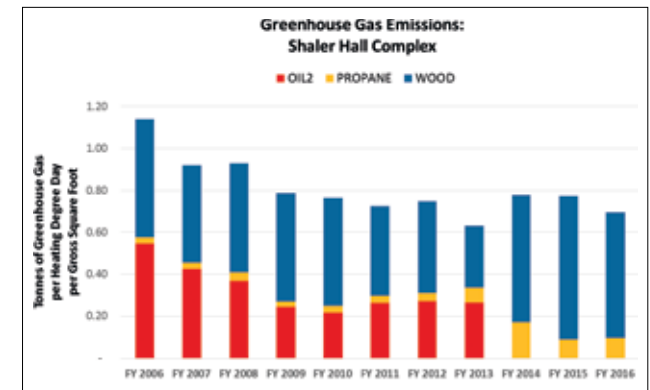
The new cordwood system heats over 51,000 square feet (the equivalent of 20 modern houses) and replaces an inefficient, fragmented, and decades-old heating system. The heating plant is made more efficient by insulation and building improvements.

The entire heating process, from log harvest to burning efficiency, is meticulously monitored by Woods Crew staff. Initial analysis of the first three winters of data is now underway by Harvard Forest scientists and students in the Wofsy/Munger lab at Harvard's School of Engineering and Applied Sciences.

The new system is a major part of the Forest's ongoing efforts to advance state and Harvard University goals for reductions in fossil fuel use and greenhouse gas emissions.



Three cordwood boilers heat a 2,500-gallon thermal storage tank. Hot water heats the 51,628 square feet of building space in a closely monitored system. In winter, the boilers are manually fed with cordwood four times a day.



A 2014 open house of the biomass system included a guided tour of the facility and related research sites, and remarks from leaders at Harvard University, the USDA Forest Service, the state legislature, and the Mass. Executive Office of Energy and Environmental Affairs.

Wood is processed by Ronald May of the Harvard Forest Woods Crew. Average wood usage since 2014 has been approximately 80 cords per year. More than 75% of campus heat is produced by the wood boilers, with the remainder covered by a propane back-up system.

Keeping It Local:
How Harvard Forest Chose to Continue a Long History of Heating with Wood

Full news article
Harvard Forest Wood Heating System

Funding Sources:



History of Harvard Forest Long-Term Ecological Research

1988

1990

1995

2000

2005

2010

2015

Chronic Nitrogen Saturation

How might a future with increased nitrogen pollution affect forest dynamics?

Forest-Atmosphere Exchange

How do forests store carbon and clean the atmosphere?

Hurricane Pull-down Experiment

How does a forest recover from a major wind-storm without human intervention?

Phenology

How is climate changing the length and timing of the growing season?

Paleoecology

What can reconstructing past landscapes from ancient pollen, lake sediments, and tree rings tell us about the forests of today and tomorrow?

D.I.R.T. Plots

What biological and physical processes control the formation of soil organic matter?

Soil warming

How might an increase in average temperature affect forest soils and their microbial diversity?



Hemlock Removal Experiment

How do ecosystems adjust to the loss of a dominant species?

Hydrology

How does water move through the forest as rain and snow?

Deer & Moose Enclosures

How do deer and moose change plant communities?

ForestGEO Dynamics Plot

How do our forests compare to others across the globe?



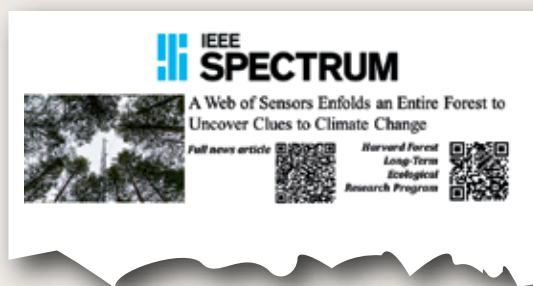
A SCIENTIFIC TREASURE TROVE

In 2009, reviewers from the National Science Foundation described the Harvard Forest Long-Term Ecological Research (LTER) program as having “repeatedly transformed the way we think about ecological systems.”

In the large experiments and permanent forest study plots of the Harvard Forest LTER, scientists and students from Harvard and dozens of institutions worldwide study fundamental and applied biophysical and ecological questions over broad scales of time and space.

The data from these long-term experiments represent an invaluable scientific legacy. The oldest experiments (now nearing the 30-year mark), and the experiments we’ve added to explore emerging environmental stressors, provide critical insights into ecological processes and directly inform sound management and policy.

Now in its 28th year, the Harvard Forest LTER is part of a national network of 25 LTER sites, the largest and longest-lived ecological network in the United States.



FOREST-ATMOSPHERE EXCHANGE (1989 TO PRESENT)

ORIGINAL LEAD SCIENTIST: Steve Wofsy (Harvard) **TODAY'S LEAD SCIENTISTS:** Andrew Richardson (Harvard); Steve Wofsy and Bill Munger (Harvard); Chris Williams (Clark)

THE BIG QUESTION: How do forests store carbon and clean the atmosphere?

WHAT WE DID: The eddy-covariance flux tower at the Harvard Forest Environmental Measurements Site (HFEMS) provides the world's longest continuous record of net ecosystem carbon dioxide exchange, evaporation, and energy flux between the atmosphere and a forest, at hourly time resolution.

We installed additional towers in a hemlock stand (2000) and a recently clear-cut deciduous stand (2009) to examine the differences in carbon flux due to species composition and stand age. The atmospheric carbon fluxes are complemented by ground measurements of vegetation and soils.

WHAT WE'VE LEARNED: At all three flux-tower sites, including an oak-dominated forest that is over 100 years old, the forest is rapidly accumulating carbon and reducing the build-up of atmospheric carbon dioxide that leads to climate change.



HURRICANE PULL-DOWN EXPERIMENT (1990 TO PRESENT)

ORIGINAL LEAD SCIENTIST: David Foster (HF) **TODAY'S LEAD SCIENTIST:** Audrey Barker Plotkin (HF)

THE BIG QUESTION: Powerful hurricanes hit New England every 50 to 200 years. How does a forest recover from a major hurricane?

WHAT WE DID: We recreated the Hurricane of 1938 in 2 acres of forest. Meticulous data from the actual 1938 hurricane determined which trees (70% of the standing timber) would be felled using a large winch. The fallen trees were left on the forest floor.

WHAT WE'VE LEARNED: Leaving a wind-damaged forest intact allows the forest to recover more quickly. The trees are younger and smaller, but many aspects of the regenerating forest — particularly soils and understory — are almost indistinguishable from neighboring forest.



SOIL WARMING (1991 TO PRESENT)

ORIGINAL LEAD SCIENTIST: Jerry Melillo (MBL) **TODAY'S LEAD SCIENTISTS:** Jerry Melillo (MBL) and Serita Frey (UNH)

THE BIG QUESTION: Climate change models predict a global temperature increase of 2–5°C over the next century. How will that affect forest soils, a crucial but changeable store of the world's carbon?

WHAT WE DID: We buried heating cables to raise soil temperature 5°C above ambient temperature year-round in three separate experiments.

In 1991, we established 6x6 meter heating plots to measure fluxes of soil gases (CH₄, N₂O, and CO₂) and nitrogen availability. In 2003, we added two large (30x30m) plots to evaluate the effect of warming on trees. In 2006, we added twenty-four 3x3m plots, some heated and some also amended with nitrogen, to further investigate below-ground processes.

WHAT WE'VE LEARNED: When temperatures rise, soil microorganisms release a pulse of carbon dioxide into the atmosphere, creating a feedback loop that could exacerbate climate change in the future. These effects diminish over time, only to re-emerge as the microbial community shifts to accommodate warmer temperatures.



HEMLOCK REMOVAL EXPERIMENT (2005 TO PRESENT)

ORIGINAL LEAD SCIENTIST: Aaron Ellison (HF) **TODAY'S LEAD SCIENTISTS:** Aaron Ellison and Dave Orwig (HF)

THE BIG QUESTION: Two possible trajectories follow the arrival of the invasive hemlock woolly adelgid in New England forests: adelgids kill hemlocks gradually, or landowners pre-emptively log hemlocks to salvage financial value. How do these trajectories affect the forest that follows?

WHAT WE DID: In a hemlock-dominated stand, we girdled two large plots of hemlock to simulate death by adelgid. In two adjacent areas, we conducted a commercial harvesting of hemlock.

WHAT WE'VE LEARNED: Logging led to abrupt, rapid changes in vegetation structure, the volume of downed/standing dead wood, and litterfall, whereas girdling (and by inference, the adelgid itself) caused slower responses of similar magnitude several years later. The young birch stands that replace hemlock are more productive, with no difference in the amount of carbon being released from soils. If allowed to re-forest naturally, stands infested by the woolly adelgid in southern New England should remain a "sink" for atmospheric carbon dioxide, despite reorganization of stand structure and species composition.





POLICY SOLUTIONS FOR ENVIRONMENTAL CHANGE

On June 2, 2014, the EPA released the nation’s first-ever carbon pollution standards for existing power plants.

A week prior, Science Policy Exchange director Kathy Fallon Lambert was already on the phone and online, circulating a new report that analyzed the forthcoming EPA rule for state-by-state impacts on air quality and public health. The report had taken over a year of advance work to synthesize, with input from scientists at the Harvard Chan School of Public Health, Syracuse University, and the School of Public Health at Boston University; and it required a nuanced understanding of the EPA process and calendar.

No easy task, but that’s what the Science Policy Exchange does best.

Based at the Harvard Forest, directed by Lambert, and coordinated by Marissa Weiss, the Exchange was founded in 2012 as a collaborative of six world-class research institutions associated with Long-Term Ecological Research sites (see page 12).

The Exchange works at the interface of science and policy to convene leaders in government, nonprofit, and corporate sectors to identify environmental knowledge gaps; partner with researchers to synthesize the best existing science; and communicate the results in ways that meet the needs of decision-makers and remain relevant to scientists and the public.

For the carbon project, two highly publicized reports in 2014 and a scientific paper in *Nature Climate Change* in 2015 highlighted the benefits of a moderately stringent and highly flexible carbon standard, which would save thousands of American lives each year from premature death related to air pollution. The paper drew world-wide media attention with coverage in approximately 600 print and broadcast media outlets.

The Exchange has launched two more initiatives, to address invasive pests and trade policy (see box on page 5) and the interacting effects of climate change and land use on ecosystems and communities (see page 6). Both projects focus on the northeastern U.S. and have national to global significance with potential for impact on major policy decisions in the next three to five years.

SCIENCE POLICY EXCHANGE

Connecting People and Science for Environmental Solutions

“A study led by Syracuse and Harvard Universities found that reducing carbon dioxide emissions from power plants can also reduce emissions of other pollutants...We know enough to know that reducing power plant emissions will make a real difference in the health of our children, our parents, and ourselves.”

— Senator Elizabeth Warren’s Floor speech on the EPA Clean Power Plan, June 2, 2014



Funding Sources:



William and Flora Hewlett Foundation
Grantham Foundation



CONSERVING NEW ENGLAND'S WILDLANDS & WOODLANDS

In the mid-19th century, New England experienced one of the globe's great episodes of environmental recovery, as millions of acres of old farmland and cut-over woods began to reforest as they were used less intensively.

In 2010, as the value of these expansive forests was just being fully recognized, a group of 20 scientists from across the region convened by Harvard Forest found that forest cover was again declining in every New England state.

The resulting report, *Wildlands and Woodlands: A Vision for the New England Landscape*, written by academic authors from across the region and published by the Harvard Forest, called for permanently retaining 70% of New England as forest, to protect the many ecological and societal benefits forests provide. 2015 marked the 5-year anniversary of this independent, academically rigorous report, which continues to be a catalyst for land protection, innovative finance concepts, and pioneering conservation policy and research.

In 2014, a group of regional experts released a complementary vision, this time for the region's agricultural future. They posited that farmland could increase from the current 5% of the landscape to as much as 15%, allowing the region's farmers to produce up to 50% of our food needs.

Today's combined Wildland, Woodland, and Farmland vision foresees a New England that is increasingly self-reliant in the production of local resources; supported in health, economy, and lifestyle by local natural infrastructure; and lessening its impact on global climate change while building resilience to environmental change to come.

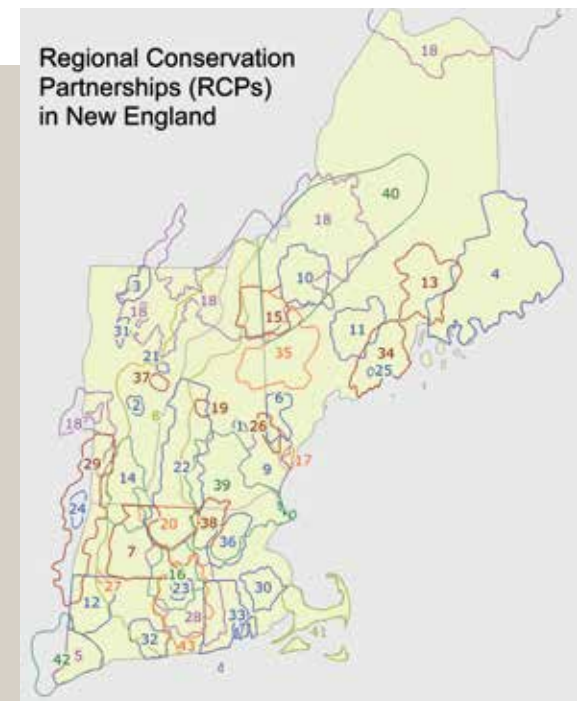
BOX 5. REGIONAL CONSERVATION AT WORK

The original Wildlands and Woodlands vision recognized that engaging individual landowners and communities is the key to successful New England conservation. The Vision proposed the formation of regional conservation partnerships (RCPs) — collaboration among existing land trusts and municipal, state, and federal agencies — as an effective means for scaling local engagement up to the regional scale.

Since 2010, New England RCPs have been advanced as a network by the Highstead Foundation, a strong partner with Harvard Forest, with leadership from Highstead's Regional Conservationist Bill Labich.

Today, 44 RCPs cover 60% of the land base of New England and eastern New York. More than \$5 million in private and federal funds have been raised to advance the network and enable conservation planning, capital campaign training, and land protection transaction costs for member RCPs.

Collectively, through the networking, new tools, and new capacity created by the RCP Network, RCPs have permanently protected about 250,000 acres of land.



Funding Sources:





Harvard faculty research mentor Andrew Richardson in the field with Summer Research student Sidni Frederick (Harvard '17).

EDUCATION

Since the Forest's founding as a university training ground for foresters in 1907, our educational footprint has expanded to include thousands of students, educators, and a range of public and professional learners. Options for Harvard students include an interdisciplinary Wintersession program, spring Freshman Seminar, House retreats, and studio courses and workshops. Our 11-week Summer Research Program, now in its 25th year, annually supports 20-30 undergraduates from throughout the U.S. in mentored, real-world research in ecology, conservation, and the humanities. Every year, more than 3,000 K-12 students and teachers learn about ecology with hands-on field research and data analysis through our Schoolyard Ecology Program. Graduate students and post-doctoral fellows study in residence and as commuters year-round.



▲ **ALYSSA HERNANDEZ**
Harvard Forest Summer Research Program 2008
Graduate student, Harvard University, Dept. of Organismal & Evolutionary Biology

"My time at Harvard Forest really impacted my life in more ways than I could even imagine. Not only did it teach me the fundamentals of how to be a successful researcher, but it also fostered my love of entomology, which is what I am pursuing now as a PhD student."



▲ **TIFFANY CAREY**
Harvard Forest Summer Research Program/ESA SEEDS SPUR 2012
Growing Green Community Organizer at People and Parks Foundation, Baltimore MD

"I left Harvard Forest with long-lasting experiences, tools, and skills that I now leverage in my position in Baltimore. I've had the opportunity to give talks and present posters at the Ecological Society of America, lead Youth Summits for inner city students, and present at non-profit and community forums.

In my academic career, I continue to use my Harvard Forest experience to strengthen my vision of obtaining a PhD and to continue my passion: examining airborne exposures in urban neighborhoods."



▲ **SAAD AMER**
Harvard Forest Winter Break Week 2013
Harvard College '16

"There's something magical about the Harvard Forest. For me, it's always been a place of refuge from the bustling chaos of Cambridge. Getting to see long-term scientific research projects definitely impacted my perception of what 'science' is, and gave a more holistic understanding of what research can be."



▶ **LISE LETELLIER**
Harvard Forest Schoolyard Ecology Teacher
Holyoke Catholic High School

"The professional development I received at Harvard Forest changed me as a professional educator. It gave me concrete methods to incorporate real science into my environmental science curriculum. Keen observations are now part of all my classwork. The support at the workshops has always been tremendous. Working side by side with Harvard scientists never intimidates me. Their openness to supporting us teachers has been invaluable."



▶ **ANDREW RICHARDSON**
Associate Professor of Organismic and Evolutionary Biology, Harvard University

"Harvard Forest is an amazing resource for both research and teaching — close enough to Cambridge that I can conveniently make day trips out, but truly a world away. My own research benefits greatly from the incredible infrastructure, facilities, and logistical support. For students, a visit to the forest makes a lasting impression, and helps to bring alive material that we have discussed in lecture or session. And for those lucky to be interns in the Summer Research Program, it is a life-changing experience."





Harvard Freshman Seminar students take a break after examining an open-grown white oak on Martha's Vineyard.



A YEAR OF EDUCATION AT HARVARD FOREST

- **JANUARY:**
- Harvard Wintersession: "Reading & Conserving the Landscape"
- Harvard Museum & Arts Fellowship
- **FEBRUARY THRU APRIL:**
- Harvard Freshman Seminar: "Global Change Biology" begins
- Spring Seminar Series begins
- **MARCH:**
- Harvard Forest LTER Ecology Symposium
- Spring Field Tours begin
- **APRIL:**
- Schoolyard Spring Workshop for Teachers
- Keystone Conservation Training
- **MAY THRU JULY:**
- Harvard Forest Summer Research Program
- Summer Field Tours
- **AUGUST:**
- Summer Research Symposium
- Schoolyard Summer Institute for Teachers
- Graduate Student & Post Doc Retreat
- **SEPTEMBER THRU NOVEMBER:**
- Fall Seminar Series
- Fall Field Tours
- **DECEMBER:**
- Schoolyard Data Workshop for Teachers



of colleges represented by Summer Research Program students in 2015 

Harvard PhD students Morgan Furze and Meghan Blumstein prepare to ascend into the canopy to collect data. ▶

Funding Sources:



G. Peabody Gardner Memorial Fund
 Mount Holyoke College Miller Worley Center for the Environment
 Bryn Mawr College LILAC Summer Internship Fund



EDUCATION: Lessons from the Witness Tree

How much can one tree tell us about climate change? In fall 2014, award winning *Seattle Times* journalist Lynda Mapes came to the Forest to find out.

The tree, a majestic 100-year-old red oak, is flanked by a stone wall and stands in the shadow of a Harvard Forest research tower. Mapes spent a year tracking the tree's stories, from its beginnings as an acorn when the Forest was first getting established, to its contemporary role as a carbon-storing, water-hauling wonder. Her book, called *Witness Tree*, will be published by Bloomsbury Publishing in 2017.

Mapes chose Harvard Forest because she wanted the writing to be an immersive experience. In her own words: "Writers need three things to tell a story well: characters, location, and a narrative, and with the forest's unique long-term historic records and scientific data; beautiful setting, and crack collaborators — including one spectacular tree — I have all three. Living in my research site, a short walk from my tree, on the historic John Sanderson Farm... there couldn't be a better way to tell this story of a changing natural world, and our relationship to it."




The Harvard College Writers' Workshop Board Retreat on a field walk with Lynda Mapes.




Writer Lynda Mapes ascends the "witness tree."



One of Mapes' many field journals.

Words **62,345**
composed
for book
& blog 

Pounds
of coffee
consumed by
author **36** 



Explore the project and see the tree's webcam at harvardforest.fas.harvard.edu/witness-tree.

"Living in my research site, a short walk from my tree... there couldn't be a better way to tell this story of a changing natural world, and our relationship to it."

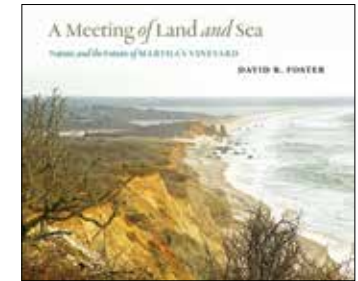
— Bullard Fellow and *Seattle Times* journalist Lynda Mapes



WHAT'S NEW

THE SHIFTING LANDSCAPE OF MARTHA'S VINEYARD

When the new book *A Meeting of Land and Sea: Nature and the Future of Martha's Vineyard* is published by Yale University Press early in 2017, it will become the most comprehensive narrative available of the history and ecology of the island. Author David Foster, Director of the Harvard Forest, has conducted research on the island with many colleagues since 1990. The book will be published with a series of unparalleled historical, modern, and interactive maps that will orient visitors and scholars alike to the rich dynamics of the land.



NEW INTERPRETIVE TRAIL

Harvard Forest's newest interpretive trail opened to the public in winter 2015-2016. Over three forested miles, the French Road Trail includes the remnants of an 18th century inn, some of the Forest's most beautiful and intact stone walls, several long-term research experiments, a vernal pool, and the Forest's oldest living tree: a 420-year-old black gum.

The trail is also available as a virtual tour created in winter 2015-2016 by Harvard undergraduate intern Caroline Juang, with support from Harvard's Office of Career Services.



MUSEUM RENOVATION

The Harvard Forest Fisher Museum dioramas, developed by the Guersney and Pitman studio in the 1930s, attract visitors from all over the world.

The Fisher Museum in Shaler Hall was built to house the dioramas in 1941, and in the 1970s, the Museum was renovated to include an auditorium space. In winter 2016-2017, with funding from the Harvard Faculty of Arts and Sciences, the Fisher Museum will be renovated for the first time in over 40 years. The dioramas will remain in place and are being protected and in some cases restored (see photo at right) by professional conservators. A new layout, plus updated lighting, flooring, and audio-visual capacity, will enhance the Museum as a learning environment and conference space for a user group that include thousands of students and professionals each year.



NEW CAMERAS IN THE SPOTLIGHT

Three new research webcams now aid the study of change on the Harvard Farm and in the hemlock forests of Prospect Hill. The cameras and electrical work were supported by a grant from the National Science Foundation's Long-Term Ecological Research program. All webcams are viewable on the Harvard Forest homepage.

Francesca Cagnacci and Nathan Ranc, a Harvard faculty and graduate student team from the Department of Organismal and Evolutionary Biology, have deployed 7 wildlife cameras in our trails and research sites, capturing beaver, deer, river otters, mink, bobcats, coyote (right), and many other animals.



◀ A 92-foot walk-up tower erected on Prospect Hill in 2014 allows researchers to collect data in the oak canopy and encourages visiting classes to consider the forest landscape in new ways.

STAFF & COLLABORATORS

» Staff

David Foster – Director

Research & Policy

Jay Aylward – Research Assistant

Audrey Barker Plotkin – Site & Research Manager

Daniel Bishop – Research Assistant

Emery Boose – Information Manager

Peter Clark – Research Assistant

Brian Donahue – Environmental Historian

Elaine Doughty – Research Assistant

Aaron Ellison – Senior Ecologist

Brian Hall – GIS Research Assistant

David Kittredge – Forest Policy Analyst

Kathy Fallon Lambert – Director of the Science & Policy Integration Project

James Levitt – Director of the Program on Conservation Innovation

Luca Morreale – Research Assistant

David Orwig – Forest Ecologist

Manisha Patel – Lab Manager & Summer Program Coordinator

Neil Pederson – Senior Ecologist

Josh Plisinski – Research Assistant

Jonathan Thompson – Senior Ecologist

Mark VanScoy – Research Assistant

Marissa Weiss – Science Policy Exchange Program Coordinator

Post-Doctoral Fellows

Matthew Duveneck

Matthew Lau

Marissa McBride

Josep Serra-Diaz

Administration

Jeannette Bowlen – Accounts Payable

Laurie Chiasson – Administrative Assistant

Edythe Ellin – Director of Administration

Jenny Hobson – Secretary

Alisha Morin – Accounting Assistant

Julie Pallant – System & Web Administrator

Lisa Richardson – Accounting Assistant

Education

Clarisse Hart – Outreach and Education Manager

John O’Keefe – Museum Coordinator (emeritus)

Pamela Snow – Schoolyard Program Coordinator

Greta VanScoy – Museum Assistant

Woods Crew

Lucas Griffith

Oscar Lacwasan

Ronald May

Roland Meunier

John Wisniewski – Woods Crew Supervisor

» Affiliates

Harvard University

Jonathan Buonocore – T.H. Chan School of Public Health

Francesca Cagnacci – Hrды Fellow, Dept. of Organismal & Evolutionary Biology

Dan Flynn – Arnold Arboretum

Richard Forman – Graduate School of Design

Michele Holbrook – Dept. of Organismal & Evolutionary Biology

Paul Moorcroft – Dept. of Organismal & Evolutionary Biology

Bill Munger – School of Engineering & Applied Sciences

Andrew Richardson – Dept. of Organismal & Evolutionary Biology

Joel Schwartz – T.H. Chan School of Public Health

Margo Seltzer – School of Engineering & Applied Sciences

Steven Wofsy – School of Engineering & Applied Sciences

Elizabeth Wolkovich – Arnold Arboretum, Dept. of OEB

Boston University

Michael Dietze

Adrien Finzi

Mark Friedl

Lucy Hutyra

Nathan Phillips

Anne Short

Pamela Templer

Highstead

Ed Faison

Geordie Elkins

Bill Labich

Spencer Meyer

Jes Siart

Marine Biological Lab

Jerry Melillo

Chris Neill

Jim Tang

Mount Holyoke College

Martha Hoopes

Barbara Lerner

University of Massachusetts–Amherst

Jeffrey Blanchard

Elizabeth Chilton

Marco Keiluwweit

David Kittredge

Lee Osterweil

Christine Rogers

Paul Siqueira

Kristina Stinson

Paige Warren

University of New Hampshire

Serita Frey

Scott Ollinger

Yale University

Craig Brodersen

Peter Raymond



Visiting research fellow Shah Khalid with HF Senior Ecologist Aaron Ellison.



of countries represented by visiting research fellows in 2015



Harvard Forest staff in winter 2014-2015.

» Affiliates, continued

Eric Davidson – University of Maryland

Stephen DeStefano – USGS Massachusetts Cooperative Fish and Wildlife Research Unit

Brett Huggett – Bates University

Emily Huff – USDA Forest Service

Wyatt Oswald – Emerson College

Shannon Pelini – Bowling Green State University

Evan Preisser – University of Rhode Island

Sydne Record – Michigan State University

Cory Ritz – NEON

William Sobczak – College of the Holy Cross

Christopher Williams – Clark University

Post-Doctoral Fellows and Graduate Students

Rose Abramoff – Boston University

Jennifer Albertine – UMass Amherst

Lauren Alteio – UMass Amherst

Mark Anthony – University of New Hampshire

Don Aubrecht – Harvard University

Meghan Blumstein – Harvard University

Xingjian Chen – North China University of Technology

Allyson DeGrassi – University of Vermont

Morgan Furze – Harvard University

Graham Dow – Harvard University

Koen Hufkens – Harvard University

Laura Hancock – UMass Amherst

Fiona Jevon – Dartmouth University

Stephen Klosterman – Harvard University

Rich MacLean – Clark University

Joshua Mantooth – Boston University

Eli Melaas – Boston University

Eric Morrison – University of New Hampshire

Amanda Northrop – University of Vermont

Grace Pold – UMass Amherst

Andrew Reinmann – Boston University

William Rodriguez-Reillo – UMass Amherst

Mustafa Saifuddin – Boston University

Emma Sass – University of Vermont

Patrick Sorensen – Boston University

Alexandra Thorn – University of New Hampshire

Michael Toomey – Harvard University

Jay Wasson – Yale University

Julia Wheeler – UMass Amherst

We honor the memory of three members of the Harvard Forest research community:

Dash Donnelly
(1988-2015)

Research Assistant
2012-2013

Andrew Kaldunski
(1989-2015)

Summer Research Program
2011

Bill Van Valkenburg
(1963-2015)
Schoolyard Ecology Teacher
2008-2015



BULLARD FELLOWS

Since 1962, the Charles Bullard fellowship program has supported advanced research and study by individuals who show promise of making an important contribution, either as scholars or administrators, to forestry and forest-related subjects from biology to earth sciences, economics, politics, administration, or law, and more recently, the arts and humanities. Bullard Fellows spend 6 months to a year collaborating with Harvard researchers, and primarily working in residence at the Harvard Forest, to investigate topics ranging from seed dispersal and biophysical modeling to sustainable forestry.



Bullard Fellows Yude Pan, Peter Thomas, Rose-Marie Muzika, and Marcy Lyman on Prospect Hill.

2015-2016 Bullard Fellows

Robinson Fulweiler

Boston University

The role of forests in the export of silica from land to aquatic ecosystems

David Kittredge

University of Massachusetts–Amherst

How landowner decisions influence future landscape change

Martha Lyman

Science, economics, and design of a natural infrastructure investment program

Jason McLachlan

University of Notre Dame

Integrating long-term ecological data into ecosystem models

Rose-Marie Muzika

University of Missouri

The role of insects and disease in forest succession

Yude Pan

USDA Forest Service

Impacts of elevated CO₂ and disturbances on terrestrial ecosystems

Josh Rapp

University of California–Davis

Climate, land-use, sugar bush management, and the New England maple syrup industry

Robert Scheller

Portland State University

Climate adaptation policies and implementation for U.S. forests

Peter Thomas

Keele University (UK)

Forest management and ecosystem services

2014-2015 Bullard Fellows

Hannah Buckley

Lincoln University (New Zealand)

Modeling the temporal dynamics of biological communities

Bradley Case

Lincoln University (New Zealand)

Uncertainties in spatial data of vegetation dynamics

Betsy Colburn

Harvard Forest

Effects of farming on soil and water

Anthony D'Amato

University of Minnesota

Stand dynamics of old-growth eastern hemlock forests

Lynda Mapes

The Seattle Times

Book project: *The Witness Tree* (literary non-fiction)

Wyatt Oswald

Emerson College

Consequences for forests and people of prehistoric climate change and insect outbreaks

Anne Pringle

Harvard University

Microbial biodiversity at the Harvard Forest

Diana Tomback

University of Colorado - Denver

Impacts of the loss of whitebark pine on ecosystems and wildlife



Shaler Hall

Image Credits:

Cover: Jenny Hobson

Page 1: Clarisse Hart

Page 2: David Foster

Page 3: David Foster; Inset: Andrew McDevitt

Page 4: Clarisse Hart; Insets: Serita Frey, Clarisse Hart, David Foster

Page 5: Lise LeTellier, Clarisse Hart; Inset: Pamela Freeman

Page 6: David Foster; Inset: Clarisse Hart

Page 7: David Foster

Page 8: Neil Pederson

Page 9: Jenny Hobson; Inset: Moshe Roberts

Page 10: Clarisse Hart, Dave Orwig

Page 11: David Foster, Jenny Hobson

Page 12: Aleta Wiley, Clarisse Hart, Serita Frey

Page 13: David Foster, Marcheterre Fluet, Audrey Barker Plotkin

Page 14: Shutterstock: Maverick

Page 15: David Foster

Page 16: Grace Barber; Insets: Karen Diep, Alexandra Kraus, Jason Hogan, Holyoke Catholic High School, Mariah Carbone

Page 17: David Foster, Clarisse Hart

Page 18: Lynda Mapes, Melissa LeVangie, Clarisse Hart

Page 19: Mark VanScoy; Insets: Clarisse Hart, Laurie Chiasson, Nathan Ranc

Page 20: Lynda Mapes, Clarisse Hart

Back inside cover: Clarisse Hart, David Foster, Brooks Mathewson

Back cover: David Foster; Insets: Jenny Hobson, Josh Rapp, Clarisse Hart, Neil Pederson



Yellow warbler at the Farm.

Design & Illustration: RavenMark, Montpelier, VT

Writing & Editing: Clarisse Hart, David Foster, Harvard Forest

Maps: Brian Hall, Harvard Forest

Printing: Villanti & Sons Printers, Inc., Milton, VT

For research publications and datasets that cover the material in this report, and the full history of research at the Harvard Forest, visit <http://harvardforest.fas.harvard.edu>.

HARVARD FOREST

Harvard University

