Forest Plans of North America

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Chapter 10

Harvard University Forest, Massachusetts, United States of America

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ABBREVIATIONS

CRs	Conservation Restrictions
ForestGEO	Forest Global Earth Observatory of the Smithsonian Institution
LTER	Long-Term Ecological Research Program of the National Science Foundation
NEON	National Ecological Observatory Network of the National Science Foundation

MANAGEMENT SETTING AND BACKGROUND

The Harvard Forest was founded in 1907, as Harvard University's outdoor classroom, laboratory, and forest demonstration area. It is a department within the Faculty of Arts and Sciences of Harvard University. From a center comprising 3,650 ac, (1,477 ha) of land, research facilities, and the Fisher Museum, the scientists, students, and collaborators at the Harvard Forest explore topics ranging from conservation and environmental change to land-use history and the ways in which physical, biological, and human systems interact to change our earth. Over the past century, major research themes have encompassed forest-site relationships, silviculture, forest policy and economics, botany, ecology, and atmospheric science. The Harvard Forest has a long history of partnerships with national networks of ecological research sites, including the Long-Term Ecological Research (LTER) program and National Ecological Observatory Network (NEON) of the National Science Foundation, the National Institute for Global Environmental Change of the Department of Energy, and the Forest Global Earth Observatory (ForestGEO) network coordinated by the Smithsonian Institute.

Located within the New England Upland physiographic region in north-central Massachusetts (42.5° North; 72° West), the Harvard Forest's rolling hills and valleys range from 722 ft (220 m) to 1,345 ft (410 m) above sea level. The bedrock underlying the terrain is a mixture of metamorphic rocks formed through continental collisions during the middle Devonian Period. Local site conditions are driven by the stony glacial tills deposited during the Wisconsin Ice Age. These are interspersed with local glacial outwash deposits and wetland peats. Soils are stony and acidic with a wide range of depth and moisture. The very few calcareous, open land, wetland, and aquatic sites contain a disproportionate amount of the floral diversity of the forest. The cool, moist, temperate climate is becoming warmer and wetter regionwide (Melillo et al., 2014). Based on meteorological records from 1961 to 1990, July mean temperature was 68.2 °F (20.1 °C), January mean temperature was 19.8 °F (−6.8 °C), with 42 in (1,067 mm) average annual precipitation distributed evenly throughout the year (Greenland and Kittel, 1997). Records from 2002 to 2013, however, show higher temperatures, especially in the winter, and possibly higher precipitation: July mean 69.3 °F (20.7 °C), January mean 23.0 °F (−5.0 °C) and annual precipitation averaged 48.7 in (1,237 mm) (Boose, 2001).

Almost all of the forests in the region are second-growth, following extensive agricultural clearing and logging that peaked in the mid-1800s (Foster and Aber, 2004). The primary forests that remain (i.e., those forests that were never cleared for agriculture) were typically utilized as woodlots. This land-use history is a primary driver of current forest structure and ongoing dynamics (Figure 10.1). The long-term trends in forest cover and human population in the six New England states show that even as the population grew, forest cover increased between 1850 and the late 1900s. In recent years, conversion from forest to developed land has begun to reverse this trend. Eastern white pine (*Pinus strobus*) declined after the 1938

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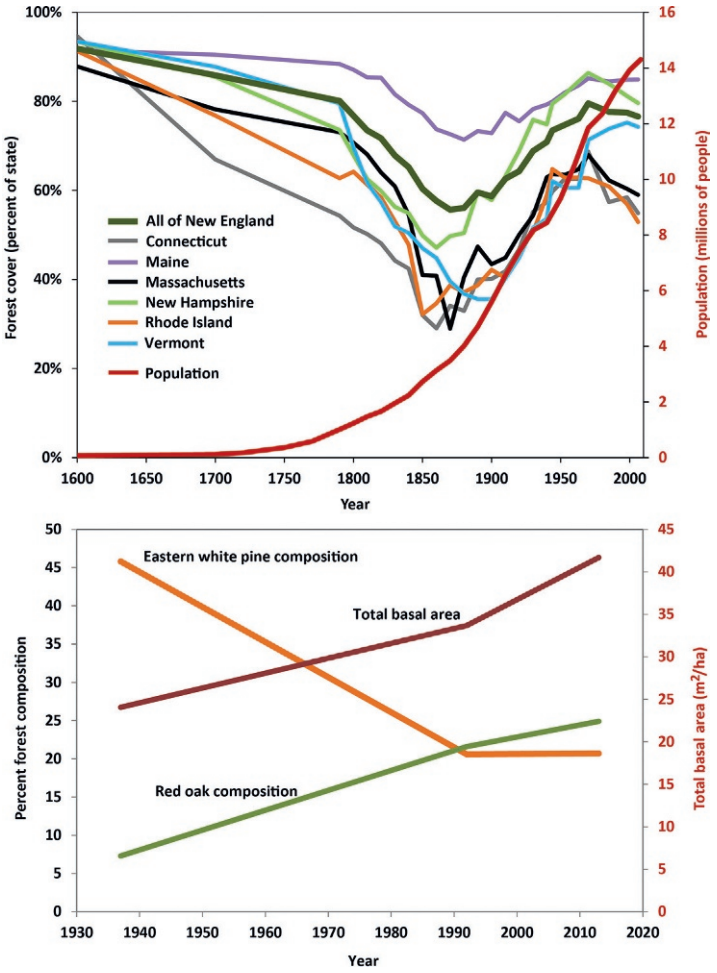

FIGURE 10.1 The regional context for the Harvard Forest (top) and forest growth and composition change at the Harvard Forest (bottom).

hurricane, whereas red oak (*Quercus rubra*) has become an increasingly important component of forest growth, based on data from 60 permanent plots at the Harvard Forest. Wind is the major natural disturbance agent, from isolated windthrown trees to extensive hurricane damage such as occurred in 1938. Pests and pathogens tend to be species-specific. The 1910s-era chestnut blight, caused by the fungus *Cryphonectria parasitica*, and the current hemlock woolly adelgid (*Adelges tsugae*) outbreak have caused long-term tree species declines, whereas periodic outbreaks of pests and pathogens, such as gypsy moth (*Lymantria dispar dispar*), have led to short-term pulses of mortality and decreased tree growth. Wildlife populations have changed substantially with reforestation and changes in hunting activity; many forest species have increased in recent decades. White-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), North American beaver (*Castor canadensis*), and porcupine (*Erethizon dorsatum*) exert subtle to significant effects on forest ecosystems (Bernardos et al., 2004).

The Harvard Forest comprises five tracts in the towns of Petersham and Phillipston, Massachusetts (Figure 10.2). Three smaller tracts are located in nearby Royalston (the Tall Timbers Tract), eastern Massachusetts (the Matthews Plantation), and southwestern New Hampshire (the old-growth Pisgah Tract; see Foster, 2014). The Prospect Hill Tract is the hub of research and educational activity, with offices, laboratories and greenhouses, the archives building, a maintenance garage and shop, housing for short-term visitors, and the Fisher Museum, which houses the Harvard Forest Dioramas. Research infrastructure across the tract includes seven research towers (Figure 10.3), two gaged headwater streams, a wireless and electrical loop, the Shaler meteorological station, many long-term plots and manipulative experiments, and an 86.5 ac (35 ha) ForestGEO plot.

The Harvard Forest is situated within the transition hardwood/eastern white pine/eastern hemlock (*Tsuga canadensis*) region of the northeastern United States, and more than 90% of the land base is forested. Major forest types include oak-maple (*Quercus* spp., *Acer* spp.), red maple (*Acer rubrum*) swales, hemlock (often mixed with hardwoods and pine), oak-pine (*Pinus* spp.), and remnant conifer plantations. Stands 75 to 125 years old dominate the forest age structure and originate from agricultural abandonment, the logging of old-field white pine, and areas with forests damaged by the historic

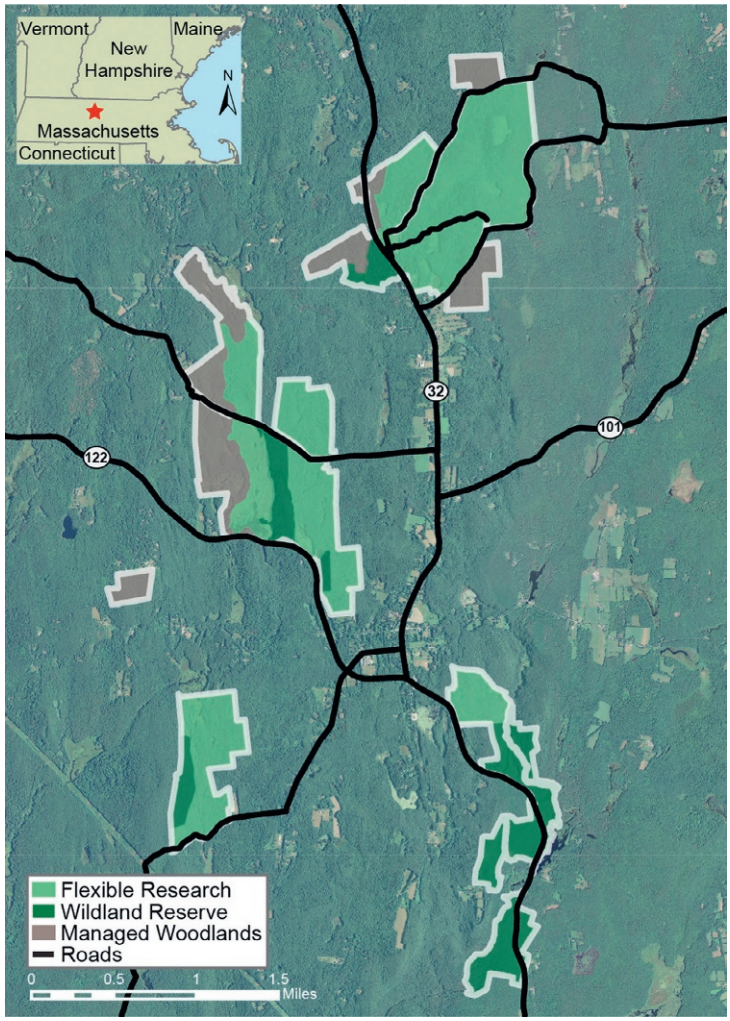

FIGURE 10.2 A map of the Harvard Forest properties showing land-use zones. All areas zoned as Managed Woodlands have specific forest stewardship management plans.

FIGURE 10.3 A canopy-view of the Harvard Forest, looking from one research tower to another.

1938 hurricane. The oldest trees tend to be hemlocks (greater than 200-years old) but scattered black gum (*Nyssa sylvatica*) trees in wetlands exceed 300 years in age. The 20 ac (8.1 ha) Pisgah Tract was never logged, but the oldest and largest trees in this magnificent old-growth forest were blown down by the 1938 hurricane (Foster, 2014). Young forests cover less than 5% of the Harvard Forest, in stands ranging from 1 to 35 ac (0.4–14.2 ha) that were created by plantation removal harvests in the early 1990s and between 2008 and 2010. Forested and open wetlands cover about 4% of the land base. Most streams

are intermittent, and headwater brooks flow into the Swift River and Miller's River watersheds. One major stream, the East Branch of the Swift River, flows through the Slab City Tract. Harvard Pond is a 70 ac (28.3 ha) dammed pond within the Tom Swamp Tract, and the Harvard Forest borders two other ponds.

Cultural features include ample evidence of the agricultural past: extensive stone walls, and foundations of historical homes, mills, outbuildings, a tavern, and a tannery. The Harvard Forest maintains approximately 100 ac (40 ha) as open pasture. Many of the current gravel woods roads (over 30 mi (48.3 km)) are formerly farm or town roads. A gate system limits access by motorized vehicles. A number of sites with limited Native American artifacts have been located.

The Harvard Forest is embedded in a heavily forested landscape. Most of the forested land in Massachusetts is owned by nonindustrial private landowners, in parcels averaging less than 10 ac (4 ha) (Butler, 2013). However, the 83,615 ac (33,839 ha) state-owned Quabbin Watershed Forest is nearby. Much of the forested land in the North Quabbin region is enrolled in current-use forest management programs or is permanently protected from development.

Current field research at the Harvard Forest encompasses more than 100 distinct projects led by more than 60 investigators from the Harvard Forest, other departments of Harvard University, NEON, co-investigators with the LTER program, and universities and research institutes from New England and worldwide. Many of the ongoing major experiments were initiated between 1988 and 1990 and include a nitrogen saturation experiment, two soil warming experiments that use buried heating cable, a simulated hurricane experiment, and chronic manipulations of above- and below-ground litter inputs. The first eddy-flux tower began monitoring forest-atmosphere carbon exchange in 1991 and is now complemented by eddy-flux measurements in an old hemlock forest and in a recently harvested forest. Associated with these towers are complementary studies of tree physiology, plot-based estimates of carbon flux in soils and vegetation, and monitoring of forest-atmosphere exchange of ozone, volatile organic compounds, and nitrogen. In addition to the recently established 86.5 ac (35 ha) mapped forest (ForestGEO) plot, there are more than 50 ac (20.2 ha) of permanent forest plots that were installed between 1937 and 2007 for a variety of purposes. They provide long-term information on forest development. Many of these long-term studies incorporate the well-documented land-use history of the Harvard Forest into their study design and interpretation of how this history influences current forest structure and function. Prototype remote sensing equipment is often field-tested at the Harvard Forest, and the field wireless network supports collection of sensor-based data streams. There are also ongoing studies of microbial ecology, small mammal and amphibian diversity and function, ant biodiversity and ecosystem function, and invasive plant populations.

Education at the Harvard Forest encompasses: (a) programs for K-12 schoolchildren, undergraduate, and graduate courses; (b) tours and workshops for professional groups; (c) self-guided trails; and (d) the Fisher Museum. Two trails that begin at the Fisher Museum are the most frequently visited, but the entire forest is utilized as an outdoor laboratory and classroom. Each summer, a group of 20–30 undergraduates from across the United States work with researchers located at the Harvard Forest to learn and collaborate on research projects.

PLANNING ENVIRONMENT AND METHODOLOGY

As the Harvard Forest enters its second century, its mission is to develop and implement interdisciplinary research and education programs investigating the ways in which physical, biological, and human systems interact to change our earth. The central focus on research and education has been unchanged since the forest's founding in 1907. The Land Use Master Plan supports this overall mission, as the overarching goal of the plan is to allow for flexibility of research and educational uses while protecting current and future research opportunities and natural and cultural resources.

Although the Harvard Forest has maintained a consistent mission and long-standing management approaches for some of its notable forest areas, much of this information is in scattered written sources originating with senior staff and directors (Fisher, 1920, 1921, 1931; Gould, 1960). As research and educational activity at the Harvard Forest increases over time, a formal Land Use Master Plan was developed to describe long-standing activities and to help guide future collaborators and leaders. The plan focuses on identifying broad land-use zones, mapping these zones across the Harvard Forest land base, and articulating guidelines for acceptable research, educational, recreational, and forest management activities for each zone. This will allow better guidance for siting new activities on the Harvard Forest, protecting sensitive areas, and providing a broad framework for our local and worldwide research collaborators.

The museum coordinator and the site coordinator led the planning process from 2004 to 2008, in close consultation with the Harvard Forest director, guided by historical documents describing the mission and goals for management and a series of discussions with the Harvard Forest research group. Early discussions helped to clarify major types of land use at the Harvard Forest and zone types. True to its mission, the primary land uses are for research and education activities. Recreational use, protection of fragile sites, and forest management are supporting uses. Informed by the Harvard Forest, emphasis on understanding ecological dynamics in the New England region resulting from natural disturbances

and environmental change, management response to forest disturbances was also considered. Based on the land-use types identified, a parallel effort was completed to compile and synthesize historical and current assessments of information about the Harvard Forest lands. These supporting documents include base maps and history of the forest, a summary of its natural resources, and current and historical policies and activities for research, education, recreation, land protection, and forest management.

At first, zones defined by use restrictions based on long-standing Harvard Forest traditions, site fragility, state and local regulations, the occurrence of long-term studies, and unique habitat values, were favored. Further discussions shaped an approach of designating reserves and active management areas within a matrix of land available primarily for research and educational use. The matrix of land zoned for Flexible Research reflects the unique mission of the Harvard Forest. As an *ecological* research forest, current major studies mentioned above suggest an emphasis that is somewhat different from a research forest focused on silviculture and forest management strategies, although this is an important part of the history of research at the Harvard Forest.

Guiding Laws, Regulations, and Policies

The Wildland Reserves and Managed Woodlands are closely aligned with the history of forest management and the regionwide Wildlands and Woodlands vision published by the Harvard Forest. Concurrent with the Harvard Forest planning process, the original Wildlands and Woodlands initiative was developed for Massachusetts, involving many researchers at the Harvard Forest (Foster et al., 2005). Since then, the vision was expanded by a large consortium of academics to encompass the entire New England region (Foster et al., 2010). The Wildlands and Woodlands vision calls for a 50-year effort to conserve 70% of New England as forest permanently free from development. Through the leadership and commitment of landowners, these conserved lands will continue to power the region's traditional land-based economy and provide environmental and social benefits for current and future generations. The Wildlands and Woodlands vision strikes a balance between active, long-term forest management and preservation. Ninety percent of forests would be expansive woodlands that are voluntarily protected from development and managed for a multiple use of forest products, water supply, wildlife habitat, recreation, aesthetics, and other objectives. Ten percent of the forestland, or seven percent of the region, would be wildlands that are established as large landscape reserves subject to minimal human impact and shaped by natural processes. Designating about 40% of the Harvard Forest land base as wildlands or woodlands reflects this larger vision and allows the Harvard Forest to serve as a forest demonstration area, although in a different form than envisioned in 1907.

Within the broad Flexible Research, Wildland Reserve, and Managed Woodland land-use zones, activities and projects are subject to state and federal regulations and internal management policies. The Massachusetts Rivers Protection Act and Wetlands Protection Act regulate activities near water bodies and wetlands. The Massachusetts Natural Heritage Program enforces state and federal endangered species protection. Timber harvesting is regulated by the Massachusetts Forest Cutting Practices Act, which includes review by The Natural Heritage and Endangered Species Program, and adherence to water quality Best Management Practices.

In addition, more than 700 ac (283 ha) of the Harvard Forest are subject to parcel-specific Conservation Restrictions (CRs; called conservation easements in most other states) held by the Massachusetts Department of Conservation and Recreation, the Massachusetts Division of Fisheries and Wildlife, Mount Grace Land Conservation Trust, and the Town of Petersham. The reduced cost of parcels with these conservation restrictions has allowed the Harvard Forest to finance the purchase of significant additional lands in the past 20 years that buffer research sites, while providing permanent protection from development. Within these areas, research and educational activities are reserved rights, as is timber harvesting if part of a long-term approved forest management plan. Much effort was devoted to crafting unique CRs that protected these rights, and these may represent the first agreements in which research-focused easements, written to allow novel and even currently unthought-of future research activities, had been developed.

Management of the Harvard Forest is also subject to memoranda of understanding with agencies utilitizing the site. The Commonwealth of Massachusetts and the Harvard Forest have an agreement that allows the state to maintain a working fire tower on Prospect Hill, and access to that tower. The NEON and the Harvard Forest have developed a memorandum of understanding that secures NEON's infrastructure and research at the Harvard Forest for its 30-year program.

The Harvard Forest has working policies on invasive species management and research and response to forest disturbances including wind, fire, North American beaver encroachment, and pest and pathogen outbreaks. Discussions to clarify and put in writing such policies is one ongoing outcome of the planning process. Finally, major land transactions, including sale or purchase of land, placing conservation easements on land, and appointment of the Harvard Forest director, are decisions that ultimately lie with the President and Fellows of Harvard College.

OUTCOMES OF THE PLAN

A land-use matrix is at the heart of the plan. Land-use zones include Flexible Research (about 60% of the land base, or 2,155 ac (873 ha)), Wildland Reserves (about 20%, or 702 ac (284 ha)), and Managed Woodlands (about 20%, or 804 ac (325 ha)). The forest management and disturbance management activities allowed in the three land-use zones are illustrated in Table 10.1. Flexible Research areas include the major experiments and research infrastructure on the Prospect Hill Tract, much of the Tom Swamp and Simes Tracts, and the northern portion of the Slab City Tract. Rugged and less-studied native forests form the major Wildland Reserves along the east side of Harvard Pond and most of the Slab City Tract, which is bordered by other conservation lands. Managed Woodlands include parcels recently acquired to buffer research areas from possible land conversion. These are suitable for active timber management, as they lack the history of intensive land-use documentation and existing research infrastructure. The 45 ac (18.2 ha) Schwarz Tract is considered a Managed Woodland, in fulfillment of the donor's intent that it "serve as an experimental area in the study of aesthetic or landscape forestry." The western portion of the Tom Swamp Tract includes large conifer plantations and 1920s-era forest management studies, and it forms the largest (470 ac, 190 ha) Managed Woodland. Where possible, Managed Woodlands and Wildland Reserves are paired; for example, the Managed Woodland on the west side of Harvard Pond complements the Wildland Reserve on the east.

For each zone, acceptable research, education, recreation, and forest management activities are defined. For example, research projects in the Flexible Research zone may include a range of intensities, from observational studies to major installations and manipulative experiments. In Managed Woodlands, research activities are allowed that are compatible with the site-specific stewardship plans and, in the spirit of long-term planning, may run for many years. In Wildland Reserves, research is limited to observational studies and low-impact sampling, although plot markers can be used to document the locations of long-term plots. The use guidelines also specify that a written research project application must be approved and updated annually for all studies. This illustrates how the land-use zones provide a broad framework, whereas specific projects are considered and sited on a case-by-case basis. Educational activities for each zone include interpretative signs

TABLE 10.1 Forest Management and Disturbance Management Activities Allowed in Land-Use Zones on the Harvard Forest

	Land-Use Zone		
Activities	**Wildland Reserves**	**Flexible Research**	**Managed Woodlands**
Forest management	• Fell hazard trees and maintain existing trails and roads	• Maintain roads and trails • Remove hazard trees • Create access and infrastructure if required by approved research and if compatible with existing research • Plantation harvest and other management as compatible with research	• Forest management as described in approved Stewardship Plan (including Best Management Practices)
Disturbance management	• Clear existing trails and roads • Precautionary/abatement measures for invasive species • Invasive plant removal	• Road maintenance and plowing if needed • Protect infrastructure • Other measures as compatible or required by research • Precautionary/abatement measures for invasive species • Eradication of all invasive species manipulations at end of experiment	• Exisiting road maintenance • Skid roads as compatible with research • Precautionary/abatement measures for invasive species • Invasive plant removal

and trails, and guided group visits are allowed. Passive recreational activities, including hiking, cross-country skiing, and snowshoeing are allowed in all zones. Hunting is allowed except in posted research areas. Limited woods roads are open to horseback riding or mountain biking.

In addition to the three major zones, a Development Envelope and a Minimum Impact area are identified. These are subzones of the Wildland Reserve (Minimum Impact areas) and Flexible Research (Development Envelope) land-use zones. No new buildings are anticipated in the near future, but identifying a suitable area where additional buildings would be placed is helpful in planning land-use and conservation activities. The one Minimum Impact area is a fragile, steep slope with erodible soils and a rare plant population.

The plan is a useful tool for siting new research activities and for communicating with research users of the Harvard Forest. In addition, the planning process identified activities and policies that needed further work. Further discussions were held to develop policies for invasive plant management and guidelines for invasive plant research, beaver management, and recreational uses of the Harvard Forest internal roads and trails. Management of open lands was not considered in the 2008 plan, but management and research planning for pasture lands is now active.

Once the Managed Woodlands were identified by the plan, detailed stand inventory and management recommendations were developed in a suite of six Massachusetts Forest Stewardship Plans. Some of these were already in place, as required for parcels subject to Conservation Restrictions. Once the suite of site-specific plans was in place, the Forest Manager then developed a 5-year projection of timber and fuelwood needs for the Harvard Forest and a recommended harvest schedule.

DISCUSSION AND CONCLUSIONS

If the Harvard Forest founding director, R. T. Fisher, were to see the current Land Use Master Plan, it would not likely be what he expected. However, he would likely appreciate its overall directions and the extent to which it is informed by historical decisions and activities. Fisher's (1920) report on the Harvard Forest emphasized practical forest production issues, so the laboratory was "for forest research and the training of advanced students in the operation of timberlands." At that time, the Harvard Forest was funded through its timber revenues, and so research, demonstration and education focused on planting non-forested lands, harvesting (mainly old-field white pine), improvement cutting, and increasing the timber volume. In 1931, Fisher noted the success of the Harvard Forest in increasing its timber volume and managing the site as a regulated forest. He also emphasized that forest management must be consistent with natural forest development and site conditions. In particular, he noted better success of managing for mixed hardwood-pine or hardwood forests after harvest of old-field white pine, rather than attempting to perpetuate the white pine type by planting. These early insights to the value of learning from natural forest dynamics are reflected in the Flexible Research and Wildland Reserve land-use zones. The choice to use broad zones in this plan originates with Foster's (2002) call for a strategy for forest conservation that recognizes change over time and takes a broad-scale approach.

Learnings and Insights

The Harvard Forest is one of the most thoroughly documented forests in the world, yet finding useful summaries of site information can be daunting. The summary maps and information compiled for the site's land-use history, natural resources, research, education programs, recreation use and policies, land protection history and efforts, and 100 years of forest management are useful starting points to share with many site users. Concurrently, many of the core stand records for the Harvard Forest were digitized and indexed, so it has become easier to use the summaries in the plan to delve into the details of a particular site. The Land Use Master Plan is also strongly complemented by the *Harvard Forest Flora* book (Jenkins et al., 2008). The compilation not only provides species accounts and location maps for all vascular plant taxa found at the Harvard Forest, but also includes a compelling narrative of the Harvard Forest's history and natural resources.

Most of the Harvard Forest has a long history of human management, from clearing for agriculture to harvesting old-field pine, and the interactions between humans and forests is the hallmark of research at the Forest. Yet, the basic policy for managing disturbances that damage or kill trees—the hemlock woolly adelgid, damage from ice-storms, windthrown stands from the next great hurricane—is to observe change and allow recovery to unfold in the absence of further intervention. This is not always a comfortable option. Witnessing the decline of beloved hemlock groves is painful (Foster, 2014), yet this studied management decision provides a valuable contrast to more active management responses often practised on other land in the region. The managers have taken an active approach in some cases, such as beaver encroachment on roads and study plots, or invasive plant populations, but these continue to be considered and debated.

The Harvard Forest management response to disturbance will be reviewed and discussed over the next decades, as the Land Use Master Plan is updated each decade. The second century of Harvard's ecological research forest will surely experience many surprises, engaging many researchers and students in the quest to observe and understand both continuity and change. The Harvard Forest Plan provides a framework for this continued exploration. The Land Use Master Plan was developed at a critical time for the Harvard Forest. As it enters its second century, the forest's research infrastructure and detailed stand and land-use history records attract a growing community of researchers and scholars who utilize the land base for research studies and educational projects. At the same time that research and educational use has increased, recreational use of the Harvard Forest has increased.

Sustainability Issues

Timber supply on the subset of woodland-zoned lands is adequate for projected needs, which are mainly for on-site use. The main ongoing need is firewood for a new, efficient, thermal biomass system, which provides heating to the five main buildings at the Harvard Forest. The system, installed in 2013, encompasses a forwarder, firewood processor, three efficient wood-burners, and a 2,500 gallons (9,464 L) hot water tank. The system is projected to use less than 100 cords (362 m^3) per year, some of which is supplied simply as a by-product of woods road maintenance with the rest from planned woodland harvest. In keeping with the research and education mission of the Harvard Forest, wood and labor inputs, and system performance and heat outputs, are carefully documented.

In addition, small amounts of sawtimber are milled on-site for construction projects at the Harvard Forest. At times, timber is harvested as part of an experimental manipulation. For example, a study implemented in 2005 to study loss of hemlock by harvesting or girdling provided the siding for a new maintenance garage. Most wood sales from the Harvard Forest are small-scale; revenues from the large plantation harvest in 2008–2009 were dedicated to funding land protection around the Harvard Forest's core research areas. The Harvard Forest land base is an important asset to Harvard University's 2008 goal to to reduce greenhouse gas emissions, including those associated with prospective growth, by 30% as measured from a 2006 baseline through calendar year 2016. Using wood harvested on-site for heat and building material, as part of a long-term forest management plan, reduces the University's carbon footprint. Enrolling Harvard Forest lands in the carbon marketplace for improved forest management is another option under consideration.

Plan Development Challenges

The Harvard Forest has a rich and deep knowledge of the forest, but lacks current, forestwide forest inventory data. The last full inventory was completed more than 20 years ago. This poses a challenge to assessing the consequences of the plan. The main difficulty is discerning what, if any, comprehensive suite of information would be most useful to the research and educational uses of the Harvard Forest. The 804 ac (325 ha) of Managed Woodlands have current timber inventories, as part of their parcel-specific Forest Stewardship Plans, but these data are less relevant to Flexible Research and Wildland Reserve zones. Traditional timber-oriented inventory data is of limited use to the broad range of ecological studies that span scales from individual organisms to regions. Ecological mapping systems, such as the U.S. National Vegetation Classification, may be more relevant but are unfamiliar to many of the researchers who use the site. The *Harvard Forest Flora* (Jenkins et al., 2008) does provide one aspect of an ecological inventory. Funding is also a barrier to conducting a comprehensive forest inventory, as most of the work of the Harvard Forest is funded by grants that are based on specific research questions.

Plan Implementation Challenges

Making the Land Use Master Plan a living, relevant guide for all users of the Harvard Forest is a common challenge to any plan implementation. Beyond making the plan available on the Harvard Forest web site, products have been developed for specific user groups. For example, maps showing suitability of the internal roads and trails for research vehicle use are helpful for researchers planning access to field sites and have resulted in less driving and fewer stuck vehicles in the forest. A different set of trail maps and signage communicate with recreation users which areas are open for hiking, equestrian, and mountain biking use. Perhaps most importantly, ensuring that the Land Use Master Plan is used by future Harvard Forest managers is critical to continuity and the sense of place developed over decades. The current director acquired most of his knowledge conversationally and through reading dispersed archival materials. A major impetus for creating the master plan was to codify that knowledge and history and to make guidelines readily accessible.

Balancing the benefits and impacts of these uses is an increasing challenge. For example, the research hub at the Prospect Hill Tract now includes long-term experiments and monitoring infrastructure that is part of the LTER program,

ForestGEO forest dynamics plot, and NEON infrastructure—including a tower, soil array, and permanent plots. These major research sites are co-located to maximize synergies among the studies, but at the same time, site impacts must be monitored and carefully controlled. Another example is increasing enthusiasm in the North Quabbin region for recreational trail networks. The Harvard Forest is open to the public, but new policies limiting equestrian and mountain bike use became necessary to protect research, especially as recreational use has increased over the past 15 years.

Other Interesting Issues Related to the Plan

The planning process has prompted us to think proactively about decision making in the face of prospective and ongoing impacts. These include, for example, the hemlock woolly adelgid's arrival and future impacts such as the next major hurricane. A somewhat unusual category in the zone guidelines is one called *Disturbance Management*. The Harvard Forest has long studied how human management response alters forest response to disturbances. For example, the regionwide response to the 1938 hurricane was to salvage downed trees, and in the process, remove surviving trees, pile and burn slash, and scarify the ground. The salvage operation following the hurricane in some ways had a larger effect on ecosystem function than did the storm itself (Foster and Aber, 2004). Salvage harvesting occurred across the Harvard Forest as well, except in one place. Against the regionwide trend and admonishments from federal and state agencies, the great windthrown pines of the old-growth Pisgah Tract were left in place (Foster, 2014). Seventy-five years later, many of these fallen giants remain, mossy but remarkably intact, providing an unparalleled glimpse into how unmanaged forests function. We hope that the Land Use Master Plan will provide a lasting framework in which long-term experiments and studies, sustained woodland management, and wildland reserves can yield insights for many decades.

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