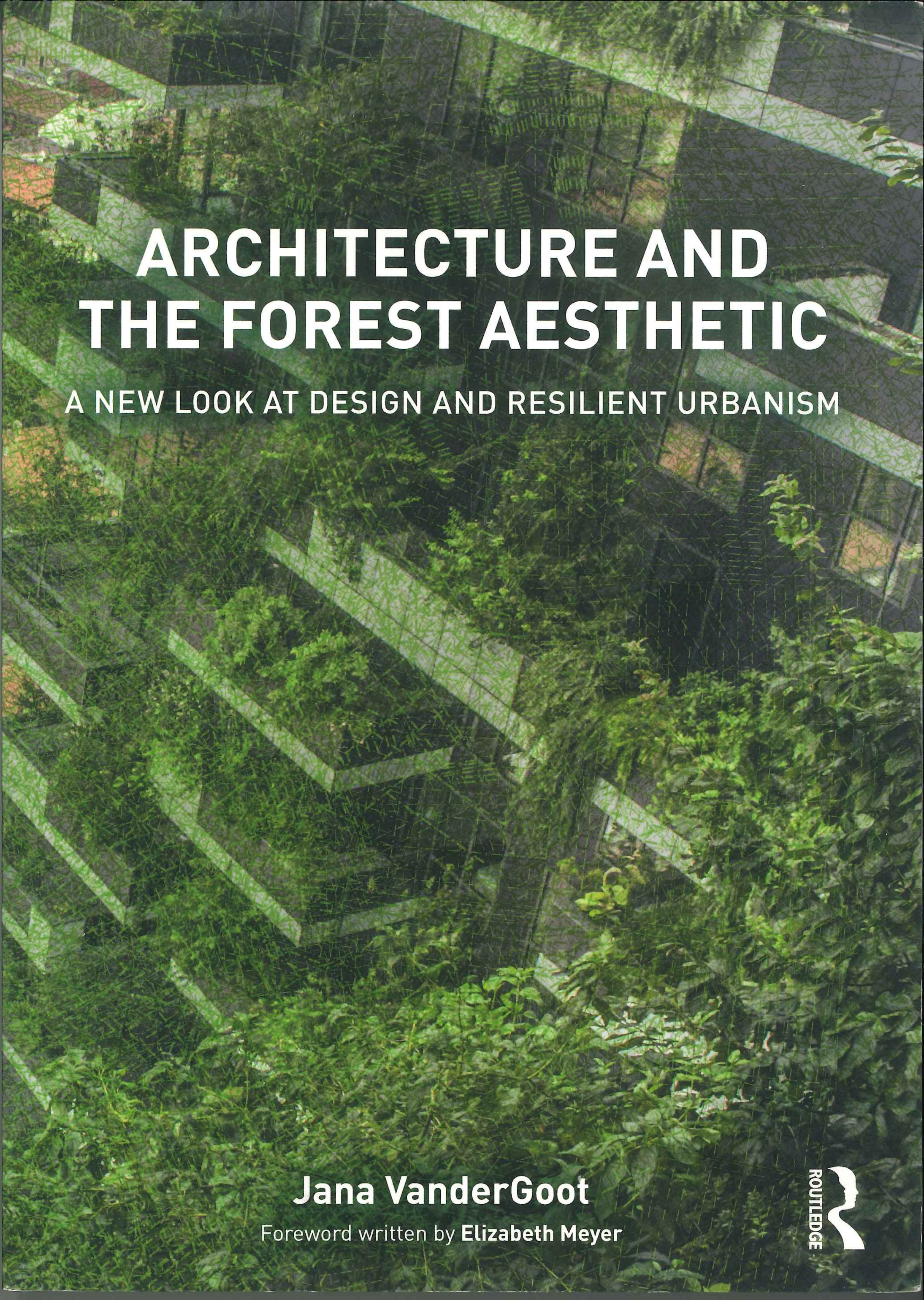

ARCHITECTURE AND THE FOREST AESTHETIC

A NEW LOOK AT DESIGN AND RESILIENT URBANISM

Jana VanderGoot

Foreword written by **Elizabeth Meyer**

ROUTLEDGE

ARCHITECTURE AND THE FOREST AESTHETIC

DESPITE POPULATION TRENDS toward urbanization, the forest continues to have a strong appeal to the human imagination, and the human preference for forest over many other types of terrain is well documented. This book re-imagines architecture and urbanism by allowing the forest to be a prominent consideration in the language of design, thus recognizing the forest as essential rather than just incidental to human well-being. In *Architecture and the Forest Aesthetic*, forest is a large-scale urban construct that is far more extensive and nuanced than trees and shrubbery. The forest aesthetic opens designers to the forest as a model for an urban architecture of permeable floors, protective canopies, connected food chains, beneficial decomposition, and resilient ecologies. Much can be learned about these features of the forest from the natural sciences; however, when they are given due consideration technically and metaphorically in the design of urban habitat, the places in which humans live become living forests.

What is present here in *Architecture and the Forest Aesthetic* is both a review of many ingenious ways in which the forest aesthetic has already been expressed in design and urbanism, and an encouragement to further use the forest aesthetic in design language and design outcomes. Case study projects featured include the Chilotan building craft of Southern Chile, the *yaki sugi* of Japan, the Biltmore Forest in the Southeastern United States, the Australian capital city Canberra, Bosco Verticale in Milan, Italy, the Beijing Olympic Forest Park in China, and more.

Jana VanderGoot is an Assistant Professor of Architecture at the University of Maryland School of Architecture, Planning and Preservation, USA. She holds a Master of Landscape Architecture degree from Harvard University Graduate School of Design, a Master of Architecture from the University of Virginia, and a Bachelor of Architecture from the University of Notre Dame. Jana is a registered architect, founding partner of VanderGoot Ezban Studio, and the 2011 recipient of the Rieger Graham Prize ICAA affiliated fellowship at the American Academy in Rome.

"VanderGoot's *Architecture and the Forest Aesthetic* productively propagates the fertile field of design culture's relations with the forest imaginary. The book gathers historic evidence and contemporary cases in support of a complex and contradictory reading of the forest as a cultural construct."

Charles Waldheim, *FAAR, John E. Irving Professor and Director, Office for Urbanization, Harvard Graduate School of Design, USA*

"The conservation future of the earth will be rooted in the interdependence of nature and society realized through an interweaving of forests, human communities, and agriculture. Jana VanderGoot opens our imagination to that vision and buoys the spirit through a thought-provoking exploration of that future in the landscape today. The result is a marvelous and important volume."

David Foster, *Director, Harvard Forest, Harvard University, USA*

"In *Architecture and the Forest Aesthetic*, Jana VanderGoot elegantly examines the history and future of wood, trees, and urban forests as the majority of people have come to dwell in cities. Ambitious and original, VanderGoot is a lively guide to arboreal projects ranging from historic woods, mycelium bricks, Beijing's Olympic Green, and the wired Harvard Forest. She culminates with the role of urban forests in places as diverse as Canberra, Amsterdam, and Detroit."

Jill Jonnes, *author*, Urban Forests: A Natural History of Trees and People in the American Cityscape

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A New Look at Design and Resilient Urbanism

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To Mary Elizabeth Petter VanderGoot

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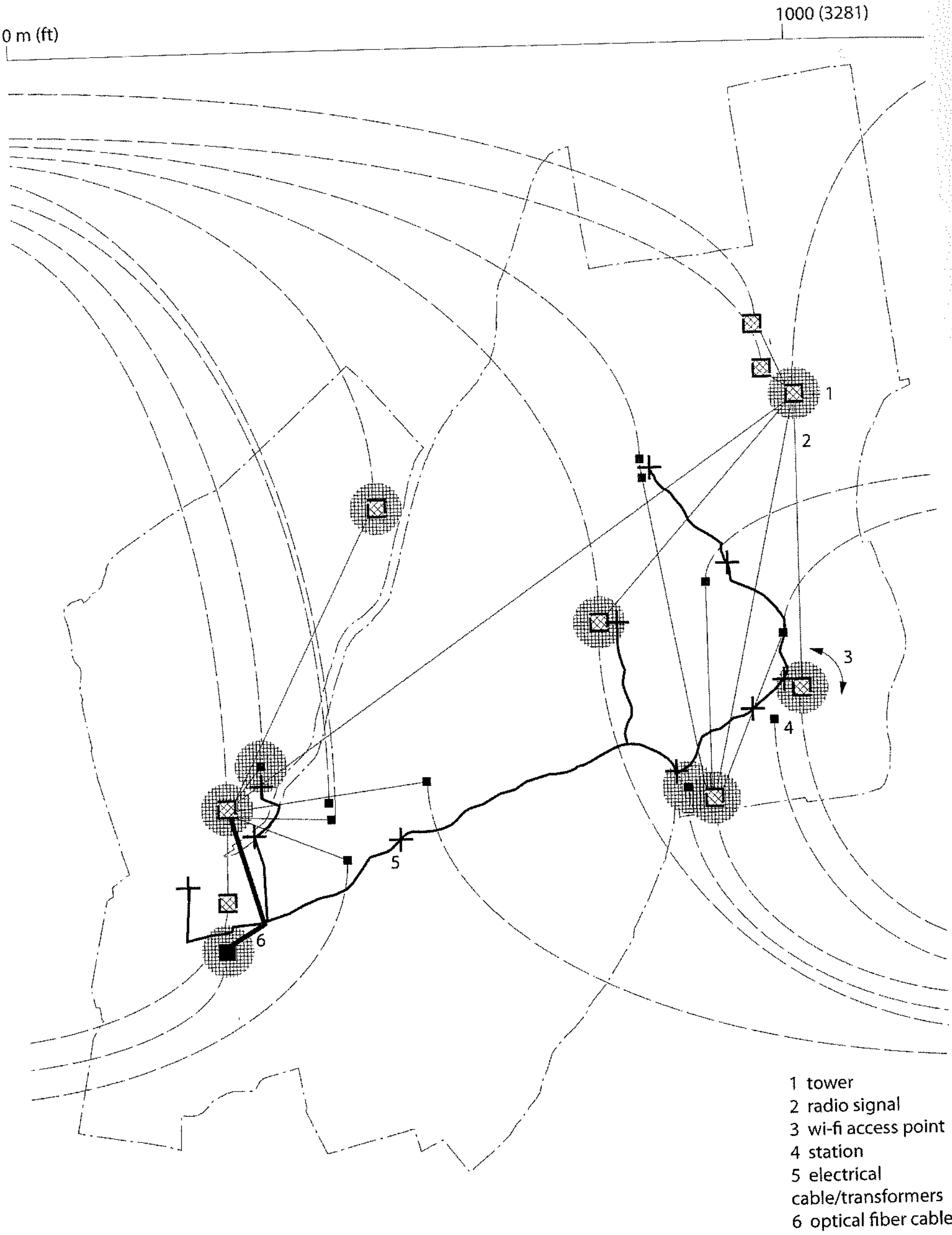

FIGURE 5.1
Signals, Harvard Forest Field Wireless Network, Prospect Hill, Harvard Forest, Worcester, Massachusetts, United States

HARVARD FOREST TIMELAPSE

Harvard Forest, University Campus
Worcester County, Massachusetts, United States
1907–present

DESIGN TACTIC: FOREST TIMELAPSE

> With practice, care, and long hours in the trenches, he was able to map the complex cycles of upturn, overturn, burial, and erosion that had accompanied and followed the uprooting of trees . . .. When he took stock of his immense accomplishments, he could envision a three-dimensional history of the old forest.
>
> —David Foster, describing Earl Stephens' 1995 thesis at Harvard Forest[1]

HARVARD FOREST IS 1,518HA (3,750ac) of managed woodlands, wetlands, and farm fields in western Massachusetts that serves as an outdoor classroom for Harvard University. It is a research facility for the Faculty of Arts and Sciences (FAS) and the Graduate School of Arts and Sciences. Dense patches of trees at Harvard Forest belie its urban character; it is a constructed landscape where goods, information, knowledge, people, vehicles, and animals move by transportation and communication networks made of signals and stones. This urbanism of signals and stones is called "forest." Its underlying matrix, its surrounding substance and foundation, is a continuing and resilient ecosystem of trees, understory vegetation, wildlife, soils and microorganisms, terrestrial and atmospheric elements, and water cycling.

Harvard Forest, with all its parts, is a three-dimensional *timelapse*.[2] It is an extraordinarily detailed, condensed picture of a dynamic process drawn out over a long period of time. The pace at which the forest timelapse unfolds is not typically associated with the human attention span or capacity for understanding. Even so, the dedicated people who have worked at Harvard Forest have found ways to read the forest timelapse, and their efforts make this forest accessible to a vast public audience. The *Forest Timelapse* at Harvard Forest, in it's most basic form, is written in signals, stones, and trees.

SIGNALS AND THE NEAR-REAL TIMELAPSE

In 1988 Harvard Forest became a Long-Term Ecological Research (LTER) Site supported by the National Science Foundation. It was around this time also that a major investment was made to introduce underground utility cables beneath forest roadbeds. These roads had first been established in the 1700s and 1800s as part of an agricultural field system and farm community.[3] Main streets and utilitarian paths that farmers once used for transporting goods, equipment, and cattle to market centers have become, in the 21st century, telecommunication and computer networking infrastructures that enable some of the world's most advanced ecological studies. Electricity for artificial light, heating, digital equipment, and the high-speed internet of the Harvard Forest Field Wireless Network (HFFW) make long-term research possible. This system for exploring forest dynamics allows instantaneous communication of near-real time data between stations deep within Harvard Forest and similar research centers across the world. [Figure 5.1]

In addition to the physical retracing of 200-year-old road infrastructure with utility cables during the 1980s, something extraordinary began to happen in the documentation of forest research and management at Harvard Forest. In the *Harvard Forest Prospect Hill Inventory 1986* data archive, Ann Lezberg notes that forest stand inventories were digitized and mapped with the Geographic Information System (GIS).[4] This digital database enabled Harvard Forest to pave the way for and participate in an expansive virtual network of ecological and climatological research.

Now in the 21st century, the data network first created in the 1980s makes possible comparison of data from long-term research sites around the globe. Harvard Forest participates in AmeriFlux, which is part of the global Fluxnet network, a component of the National Aeronautics and Space Administration (NASA) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC). Since 2011 Harvard Forest has also been the Northeast Core site for the National Ecological Observatory Network (NEON) funded by the National Science Foundation.[5] Most recently Harvard Forest is part of the Center for Tropical Forest Science Global Earth Observatory (CTFS-ForestGEO), a multi-institutional group of over sixty forest research sites from around the globe. [Figure 5.2]

Starting in 2010, Harvard Forest's Field Wireless Network (HFFW) began to enable remote access to near real-time datasets collected at study sites throughout the forest by weather stations, stream gages, webcams, and other equipment. One of these real-time data collection projects involves a network called PhenoCam. It uses webcams to gather high resolution digital images from hundreds of sites in the United States and Canada to track leaf-out (the moment in the spring season when trees and plants begin to grow new leaves) and flowering, changes in leaf color during autumn, canopy density, and light transmission in forests throughout the seasons. Webcams at Harvard Forest are mounted in several different ways.[6] Some cameras are positioned over the tree canopy as high as forty meters above the forest floor; others are just under the canopy pointing downward or mounted on the ground pointing upward. Serial images captured every thirty minutes are able to represent in just a few minutes the processes that in actuality take place over whole growing seasons or longer.

Multiple PhenoCam recordings compiled together become a rich timelapse picture that reinforces the biological interdependencies of spatially distant sites within Harvard Forest and beyond. This resource is made available to the public. As the images build over time, the Prospect Hill hemlock forest, the 100-year-old red oak Witness Tree, and the Environmental Measurement Station Eddy Flux Tower (EMS) collection will begin to confirm, with vivid photographs that are understandable and accessible to the non-expert, that spring season is coming significantly earlier than it was just three decades ago.[7] [Figure 5.3] [Figure 5.4]

The PhenoCam timelapse is a powerful design, management, and public relations tool in an era of climate change. It sets a standard of practice that could be productive in the construction of 21st century "smart cities." Real-time, PhenoCam images and urban atmospheric measures that are highly visible and evocative will allow the public to understand how lifestyle decisions on a daily basis affect climate and ecological systems.[8] While the ethics of cameras in streets and public plazas is a complex matter, the placement of PhenoCams that monitor urban tree canopies is a feasible proposition.

Lynda Mapes, author of the forthcoming book *Witness Tree*, suggests that the study of "the canopy as the proxy for the machinery of the forest" offers insight into the dynamics of warming global temperatures, elevated CO_2, and nitrogen deposition as they relate to the many organisms within the forest entity.[9] Each species has its own distinct phenological response to temperature and nutrient cycles. But the forest canopy also functions as a unit on a global scale to induce shifts in the chemical composition of the biosphere and atmosphere throughout the seasons.

The Hemlock Eddy Flux Tower installed at Harvard Forest in 2013 measures carbon dioxide concentration, water vapor, and three-dimensional wind above the forest canopy. It records a measure every five seconds. Net exchanges between the atmosphere and biosphere are recorded every half hour. The eddy-covariance flux tower at the Harvard Forest Environmental Measurements Site (HFEMS) has been taking measurements of net ecosystem CO_2 exchange, evaporation, and energy flux between the atmosphere and forest since 1989.[10] [Figure 5.5]

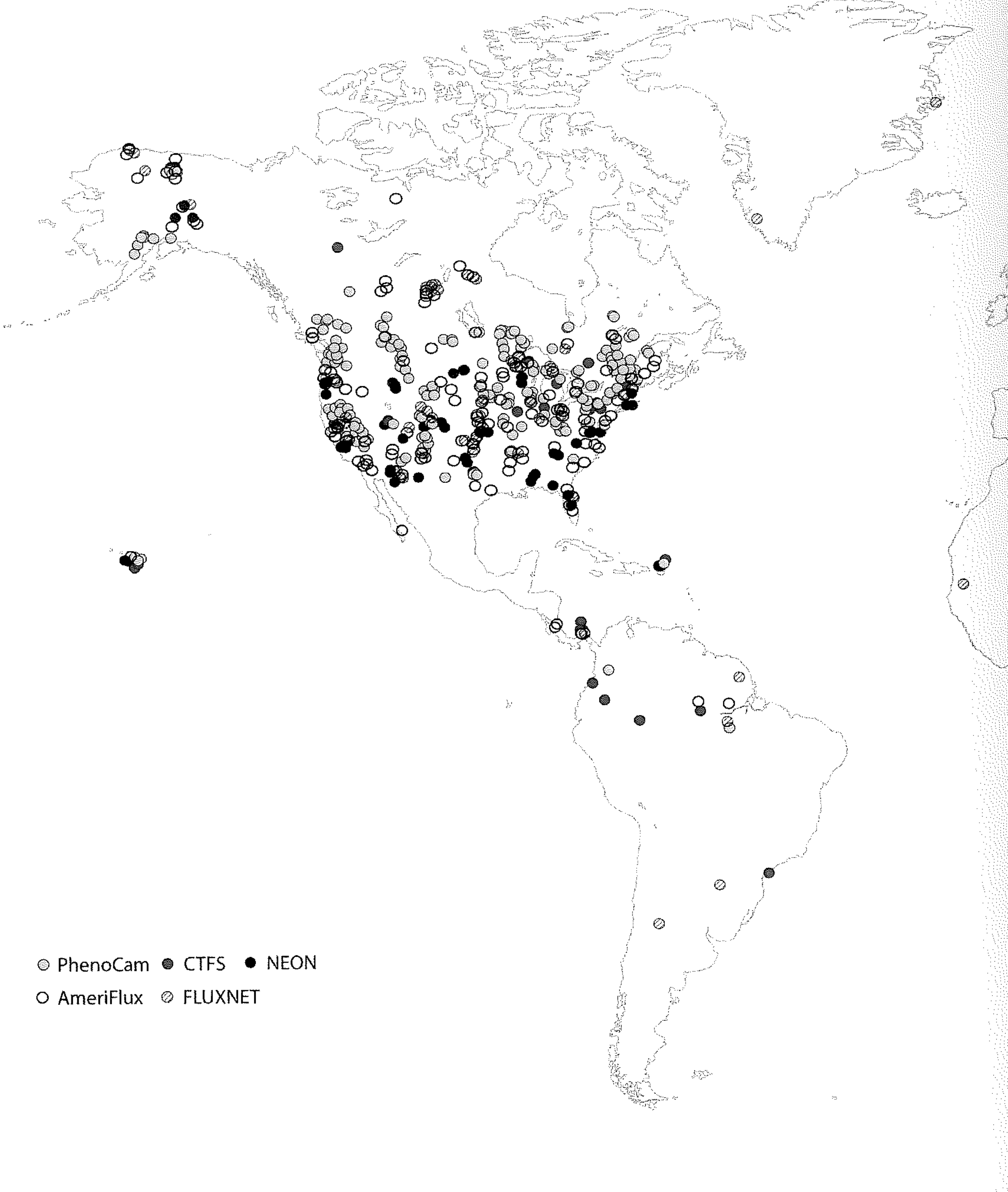

FIGURE 5.2
Global sites network, Harvard Forest, 2016

FIGURE 5.3
Hemlock Walk-up Tower, Prospect Hill, Harvard Forest, 2016

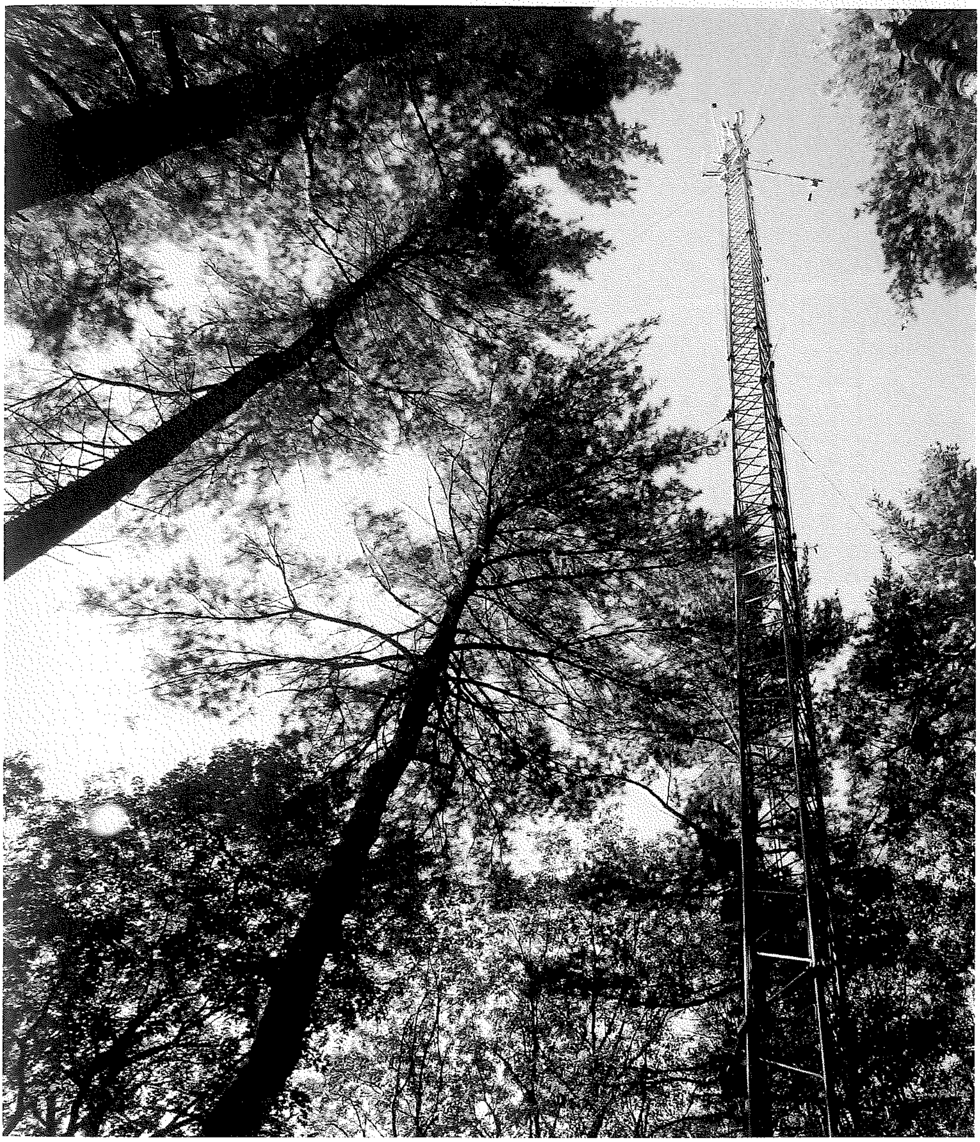

FIGURE 5.4
Barn Tower, Prospect Hill, Harvard Forest, 2016

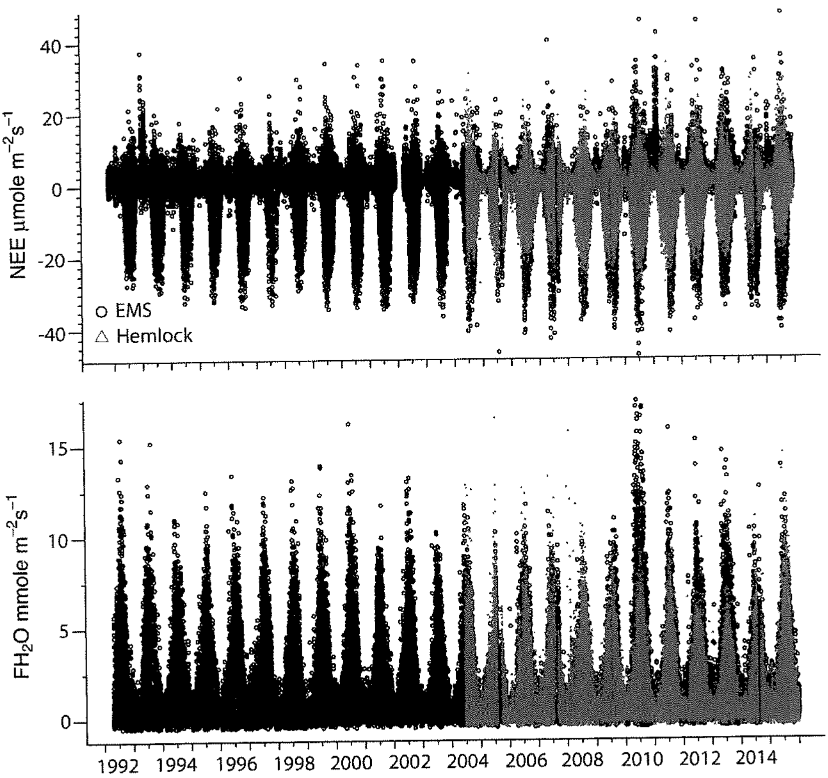

FIGURE 5.5
CO_2 and H_2O flux data, Hemlock and EMS towers, Harvard Forest, 1992–2015. Data suggests a recent decline in magnitude of CO_2 uptake by Hemlocks in summer (peak values are less negative), which is when the Hemlock woolly adelgid has become more abundant

Ground-based measurements at Harvard Forest are also taken using soil respiration chambers that look like a cross-section of plastic plumbing pipe. The data derived from them allows comparisons with tower-based measurements of carbon dioxide, hydrocarbons, nitrogen oxides, and ozone. Net changes are studied in concert with the changes in individual tree species. As dying trees decay they release their stores of carbon. To record this process, individual trees are outfitted with wires and devices that sample bark respiration. [Figure 5.6]

The timelapse record from the two towers and the soil chambers has been compiling incrementally over the last twenty years. It provides a remarkable *design specification sheet* (to use a technical term from the architecture profession) that describes the performance of a living building material. This forest specification is a ground-breaking resource not only for scientific investigation, but also for urbanism and the design disciplines. The forest can be treated as an architectural vernacular, a material and design language that has been tested, studied, and is known. A future urbanism that positions the forest as an architectural building block in the creation of human habitat is drawing on a highly effective, long-term infrastructural strategy for balancing carbon cycles and maintaining air quality in urban areas.

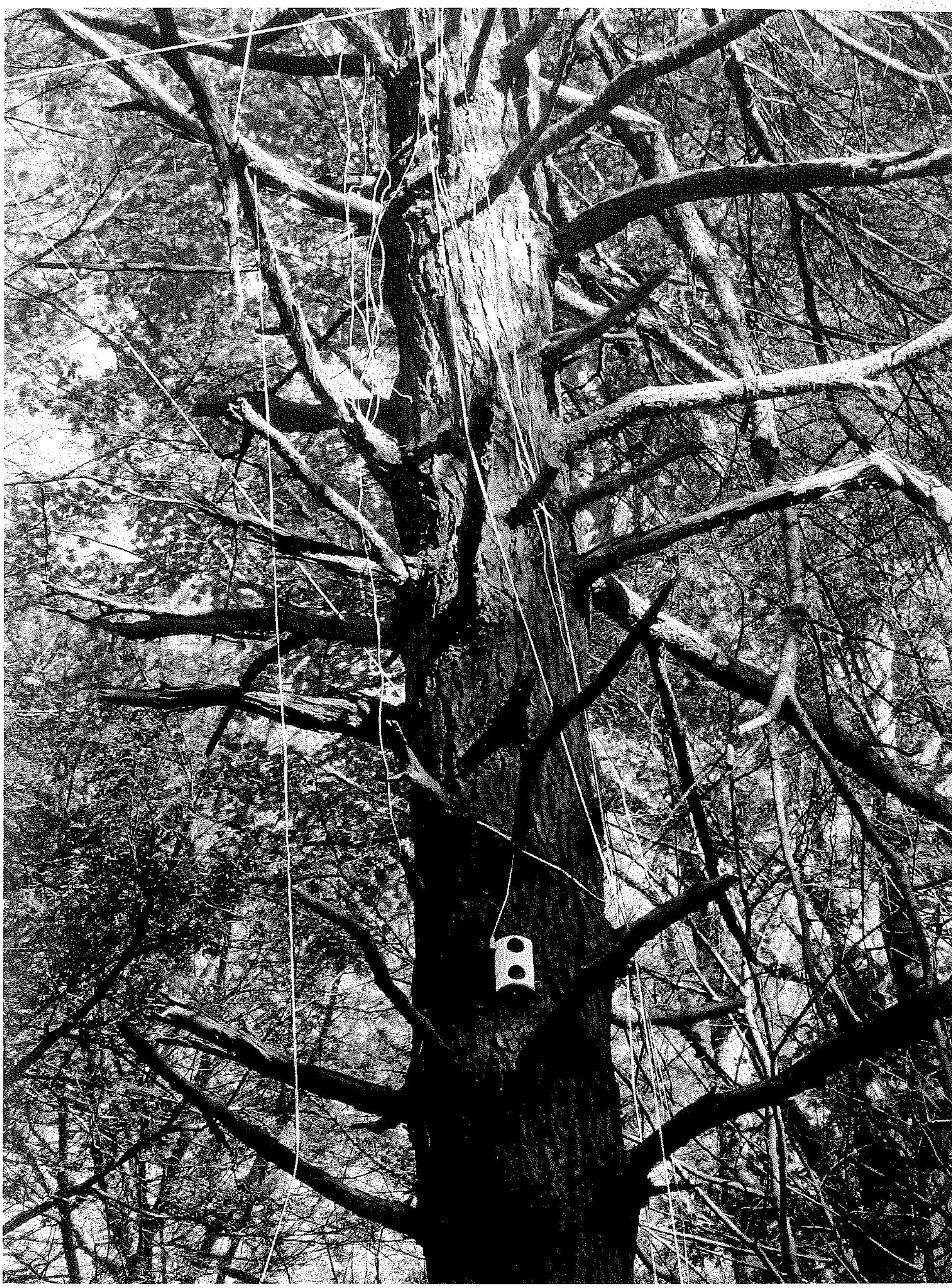

FIGURE 5.6
Bark respiration-monitoring equipment, Prospect Hill, Harvard Forest, 2016

STONES AND THE STILL SHOT TIMELAPSE

HARVARD FOREST IS A CONTEMPORARY LANDSCAPE made virtual, transportable, and widely accessible to a vast remote public by a mostly invisible wireless signal system. It also continues to be a site that is physically compelling in situ. Material leftovers of earlier transportation corridors remain as rows of stacked stone running parallel to road clearings in the forest. These stones cropped up abundantly in agricultural fields during the 1700s and 1800s and got in the way of the farmers' plows. As they were removed the stones were put to good use on site to make walls that delineated boundaries of ownership and land-use. Architecturally the stones worked as foundations for wood fencing that penned cattle during their overnight stops along the road to Brighton slaughterhouses and Boston markets.[11] [Figure 5.7] [Figure 5.8]

FIGURE 5.7
Stones walls along roadside, Prospect Hill, Harvard Forest, 2016

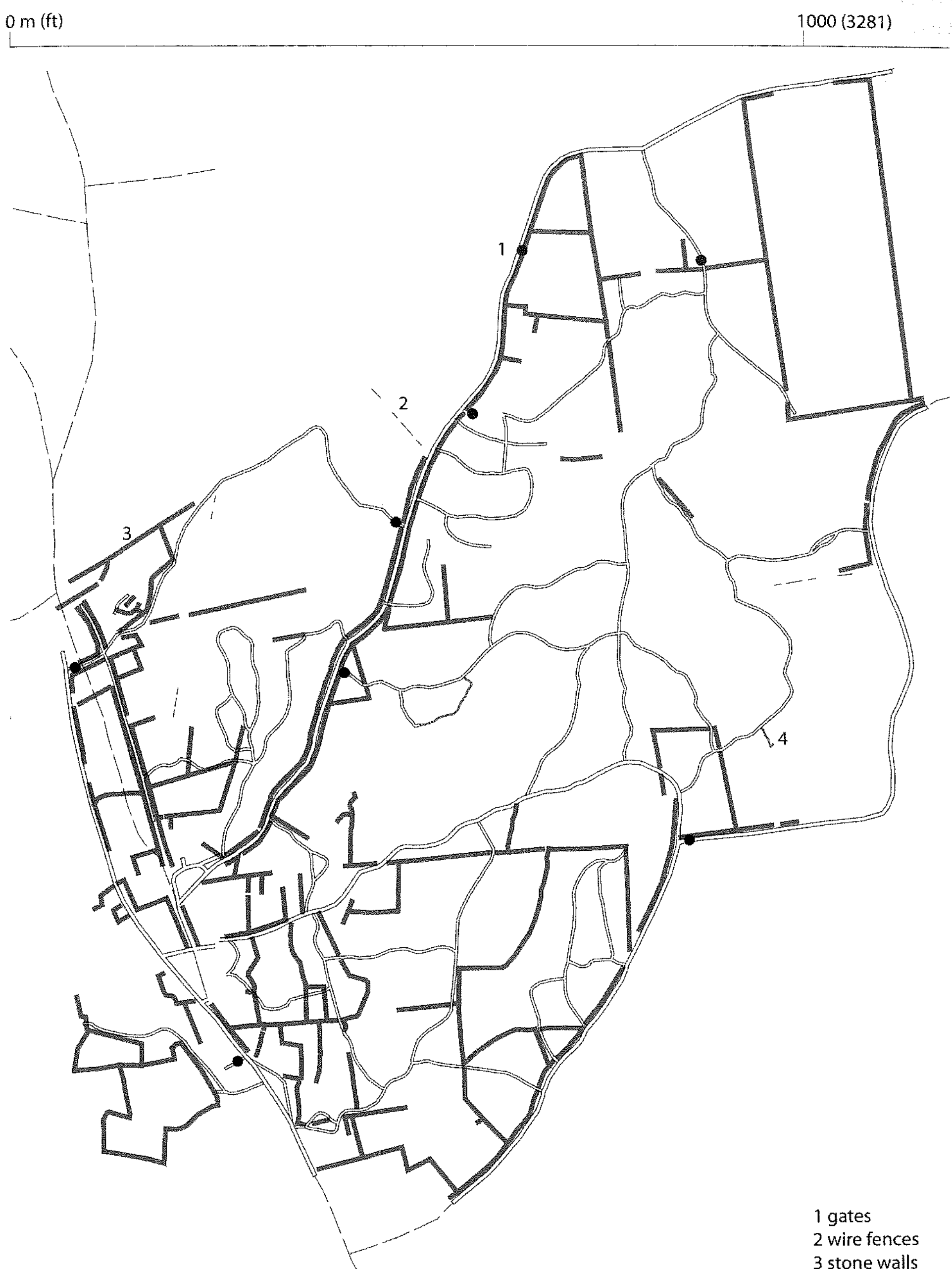

FIGURE 5.8
Stones walls, Prospect Hill, Harvard Forest

The task of unearthing the stones is a reminder of the substantial effort that was required to make an agricultural lifestyle in a landscape not ideally suited for it. In 1966 Hugh Raup, who was then the Director of the Harvard Forest, wrote an article he entitled "The View from John Sanderson's Farm: A Perspective for the Use of the Land" in which he describes southern New England fields as follows: "Our upland sandy loam soils are droughty and essentially infertile. They can be made productive but only by rather heavy fertilization. They are stony, and the fields have always been small."[12] Despite what Raup observes about the landscape, humans continued to farm as long as market demand ensured profits for selling crops.

The stacked stones at Harvard Forest remain as a testament to how extensively the forest has been modified to fit shifting patterns of human settlement. Well before the stones were removed, the existing forest had to be cleared to make space for agricultural fields. By 1850, clearing was so extensive that forest cover in Massachusetts had dipped to 30 percent of the total land area in the state. As farming declined and trees began to self-plant in the fields, the forest itself was cultivated and harvested to meet a new demand for pine shipping boxes and wooden barrels. By the end of the 20th century forest cover had risen to 70 percent. To improve timber yields the stone walls and roadsides were converted to logging roads that provided access to the woodlots and forest.[13]

The stone walls endure in the 21st century as stable, unrelenting remains of Harvard Forest's agricultural past. They are a still shot against which to view the trees that have grown back after first being cleared for agriculture. After regrowth these stands were blown down by hurricane winds after which they were harvested for timber, and then once again grew back. In the 21st century forest cover is declining sharply and being replaced by asphalt and concrete development projects that are more permanent in nature than the clearing that took place for agricultural fields and timber harvesting.[14] In this contemporary scenario where forest cover is again being replaced by other land uses, the stacked stone still shot timelapse is worthy of contemplation. The stones record the ramifications of human decision-making about land-use, and they highlight the forest's ability to recover after immense change. They endure as an example of a more permanent, albeit small in scale, modification of the forest landscape and may help inform dialogue on fitting materials and methods of permanent development in the New England of the future.

TREES AND THE THREE-DIMENSIONAL ARCHIVE

ALONGSIDE THE HUMAN-DRIVEN AGRICULTURAL legacy that the stacked stone timelapse indexes is evidence of the energy directed since the 1850s into the production of trees without human intervention. David Foster, Harvard Forest's director since 1990, reconstructs the narrative of trees advancing into abandoned agricultural fields in New England during the late 1800s in his book *Thoreau's Country: Journey Through a Transformed Landscape*:

> Tilled field went to pasture, where it supported scraggly livestock as the pasture then went to shrubland and finally to forest. A struggle often ensued. Cows would

> continue to graze the grasses as the pines invaded the pastures . . . eventually the new trees would overtop and crowd out the cows and win the battle. The farmer, sensing the futility and inevitability of the process, would drive the cattle out and would reluctantly accept his role as owner of a new woodlot.[15]

The 2010 publication, *Wildlands and Woodlands: A Vision for the New England Landscape*, calculated that roughly 79 percent of New England had returned to forest following the intense period of agricultural clearing in the 1700s and 1800s.[16] The biological and arboreal vigor to which this statistic attests reveals itself in times of rapid ecological transition. On Harvard Forest's Prospect Hill Tract, eastern hemlocks (*Tsuga canadensis*), infested with the insect pest "hemlock woolly adelgid" (*Adelges tsugae*), fall and leave sunlit openings in the forest canopy. In those spaces black birch (*Betula lenta*) seedlings are released and quickly grow into dense thickets over a few growing seasons.

In just twenty years, which is short in the lifespan of forest trees, a new birch forest can replace the declining hemlocks. In the new birch forest the hemlock will continue to exist in a different form. It will be archived as decayed wood and needles, as the pits and hills of the forest floor, the functioning of hydrological systems, and even through the birch tree growth patterns. The case of Harvard Forest's hemlock-birch grove illustrates how the forest acts as a timelapse. It is a three-dimensional archive of the past. Previous land-use and events can be traced through tree age, location, and species composition.

In 1948 Earl Stephens, a Harvard Forest student, did a thesis project at the Harvard Forest. He embarked on a groundbreaking analysis of a three-dimensional forest archive. Working with the notion that the forest was akin to a library's special collection, Stephens determined to access the data. To do so, he took apart all the trees in a 10m (33ft) wide strip of ancient woodlands. His methods included a clear-cut of the trees, slicing each tree into discs, and thoroughly surveying the forest floor to record tree root patterns, soil horizons, and shifts in topography that signaled anomalies like tree stumps and wind thrown logs.

In time Stephens was able to determine how the forest was made. He developed a detailed three-dimensional chronology for every tree by discovering how and when weather events, pathogens, and insect pests had disturbed the forest and different trees species within it.[17] The Stephens study influenced Harvard Forest's approach to ecology. In the 21st century, knowledge of historical events is deeply imbedded in the study, experimentation, management, and decision-making at the forest.[18] [Figure 5.9] [Figure 5.10]

The case of the hemlock forest on the Prospect Hill Tract offers a good example of Harvard Forest's historical approach to ecology and its use of the forest timelapse. By piecing together the story of the Prospect Hill hemlock grove with the aid of farm records, maps, and archeological surveys, the researchers were able to discover why hemlocks on this tract have remained for so long. The farmer who owned the land prior to Harvard Forest did not clear the hemlocks as he had other tree species and patches of forest because he was also a tanner and valued the tannin in the hemlock bark as a

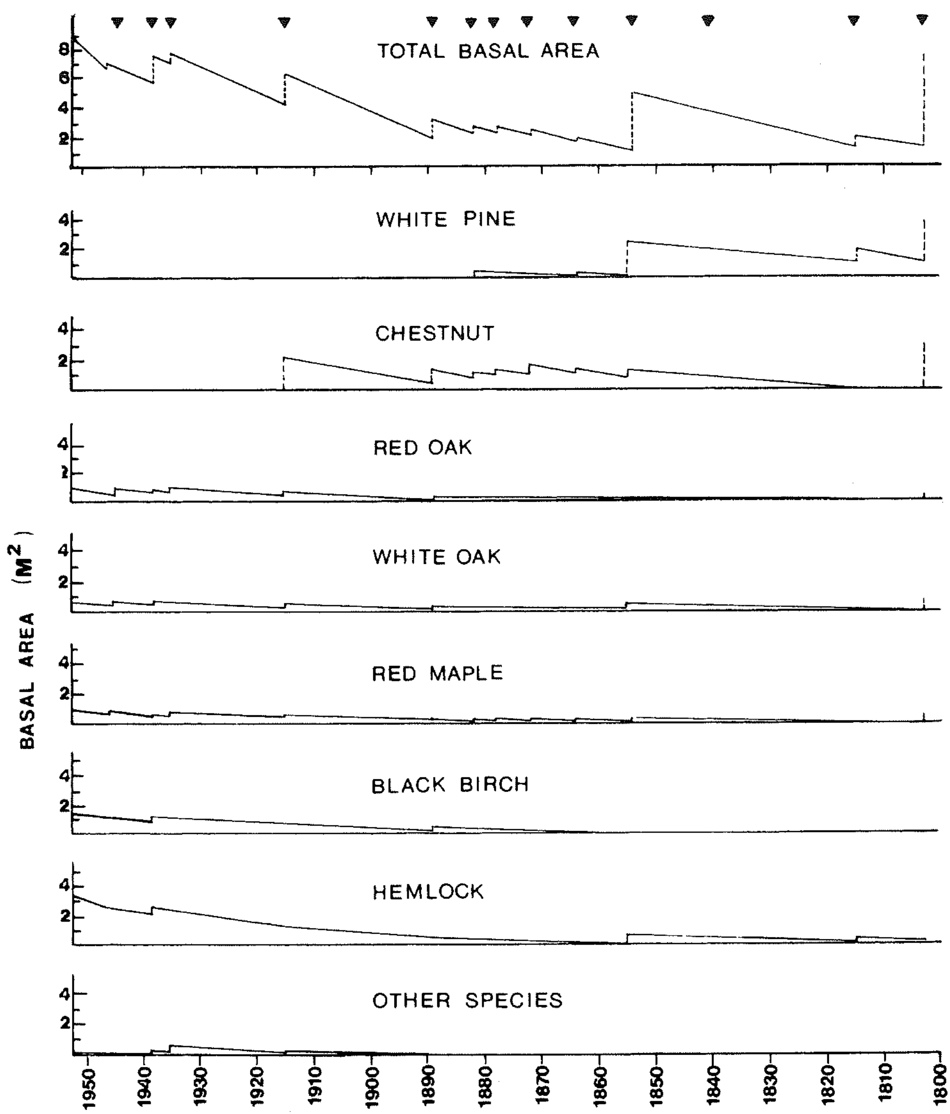

FIGURE 5.9
Change in basal area on the Tom Swamp transect between 1803 and 1952. Triangles note times of disturbances (From Stephens 1955). Chad Oliver and Earl Stephens, 1977

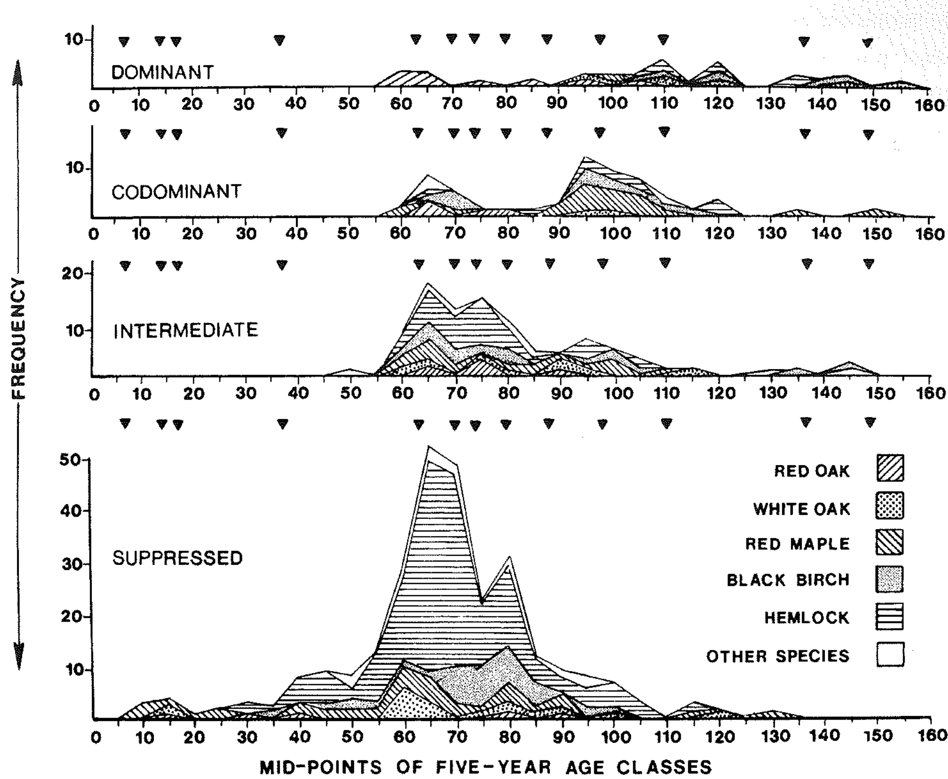

FIGURE 5.10
Harvard Forest distribution of species by age and crown class. Triangles note times of disturbances. Chad Oliver and Earl Stephens, 1977

necessary material for his leather tanning business. In the 21st century some of the hemlocks remain and are as old as two hundred and fifty years.[19]

More recently the hemlocks on the Prospect Hill have become infested with the hemlock adelgid that is a widespread threat to hemlocks along the entire eastern seaboard of the United States. Harvard Forest has decided not to intervene with pesticides, remove affected trees, or to try to salvage log the hemlocks for economic return on the wood. As the hemlocks fall, Harvard Forest will leave the logs in place.

The motivation behind these decisions reflects what has been learned in the years since the Great Hurricane of 1938. Huge swaths of trees all across the northeast were blown down by forceful winds, and Harvard Forest made a controversial decision at that time to leave the logs in Pisgah Forest in place, instead of clearing them. This patch of forest in Pisgah was recognized as one of the few remaining ancient woodlands in the region that had not been disturbed by logging, agriculture, or other forms of development. Harvard Forest wanted to study the continuity of this forest and how it would recover from the hurricane without intervention on the part of humans. [Figure 5.11]

FIGURE 5.11
Tree damage from hurricane of 1938, Prospect Hill, Harvard Forest

Over a period of seventy-five years the untouched logs, which were once seen as the outfall of a disaster, have come to be seen as a scientific treasure. They are a critical component of a healthy forest ecosystem. Data recorded at Pisgah has helped researchers at Harvard Forest in the 21st century understand the ability of the forest to recover on its own. The downed trees play a significant role in supporting the health of the forest ecosystem.

By letting the hemlock grove on the Prospect Hill Tract decline without human intervention to slow the advance of the adelgid, Harvard Forest has drawn upon past lessons learned at Pisgah. It has also actively designed an opportunity to study the effects of the non-native insect pests and pathogens that move around in an ecosystem that is the scale of the globe. Once again Harvard Forest is constructing a three-dimensional forest archive that is rich with valuable data.

Trees at Harvard Forest are part of a unique three-dimensional forest archive, but they also have been effectively protecting historic materials like the stacked stone since the 1800s. Forest cover and the small pools of water that collect under forest canopy shade have kept built-up layers of soils intact. These soil beds are composed of decaying wood and leaves, bits of charcoal, insects, and pollen that record an ecological history that dates back thousands of years. The consistent presence of forest cover has meant that researchers can continue to learn about the land's agricultural and ecological history. In this sense the forest is also a valuable utility just as the constructed signals and stones are valuable.

URBANISM AND THE FOREST TIMELAPSE

HARVARD FOREST ILLUSTRATES THE WAYS that forest can be a multivalent urban land-use type. It is something other than the periphery of development or an obstacle that needs to be cleared in order for development to occur. As an inspiration for the disciplines of architecture and urbanism, Harvard Forest has shown that a forest may be understood as either a base condition or a protective overlay for commercial, residential, industrial, and civic programs in even the most urban areas of New England. One of the many benefits that might result in designing with attention to the forest is the possibility of engaging and preserving the *Forest Timelapse*.

NOTES

1. David R. Foster, "Lessons from Harvard Forests and Ecologists. III The Earl Stephens Plot," in *Hemlock: A Forest Giant on the Edge* (Ed.) David R. Foster et. al. (New Haven, CT: Yale University Press, 2014), 174–176.
2. *Forest Timelapse* is a term applied to Harvard Forest by the author (JVG).
3. The cables buried under the roadbeds were discussed with David Foster, director of Harvard Forest, at Harvard Forest on September 18, 2015. The information was confirmed with Emery Boose at Harvard Forest, the Harvard Forest Field Wireless (HFFW) map, and Geographic Information System data. HFFW map accessed September 28, 2015, http://harvardforest.fas.harvard.edu/research/field-wireless and GIS data: http://harvardforest.fas.harvard.edu/gis-maps. GIS data reference: Hall B. 2005. *Historical GIS Data for Harvard Forest Properties from 1908 to Present*. Harvard Forest Data Archive: HF110.

4. Plantations, 1903–1993. Folders 1–153. Forest Inventories for Harvard Forest Plantations. Harvard Forest. Prospect Hill Inventory 1986, Ann Lezberg's Notes on IDRISI. Page (seq. 10232), accessed October 3, 2015, http://nrs.harvard.edu/urn-3:FCOR.FORST:1378489.

5. Harvard Forest, "Harvard Forest History," accessed September 29, 2015, http://harvardforest.fas.harvard.edu/history.

6. Harvard Forest, "PhenoCam," accessed September 30, 2015, http://phenocam.sr.unh.edu/webcam/about/ and http://harvardforest.fas.harvard.edu/webcams.

7. Jeff Gilles, "The PhenoCam Network Tracks Changes in Ecosystem Timing Across North America," *Environmental Monitor* (July 3, 2014), accessed July 9, 2016. Andrew Richardson, associate professor of organismic and evolutionary biology at Harvard University and principal investigator on the PhenoCam project, suggests that PhenoCam is a method of communicating climate change to the general public.

8. Rob Kitchin, "The Real-time City? Big Data and Smart Urbanism," *GeoJournal* 79, no. 1 (2013): 1, doi:10.1007/s10708–013–9516–8. Kitchin defines the term "smart cities" as those "increasingly composed of and monitored by pervasive and ubiquitous computing and . . . whose economy and governance is being driven by innovation, creativity and entrepreneurship, enacted by smart people."

9. Lynda Mapes, *Witness Tree* film, directed and produced by Patrick Wellever (MIT Knight Science journalism program, Massachusetts Institute of Technology, Cambridge, MA, 2015), accessed September 30, 2015: http://harvardforest.fas.harvard.edu/witness-tree. Mapes was 2014–15 Harvard Forest Charles Bullard Fellow and 2013–14 Knight Science Journalism Fellow at MIT.

10. S. Urbanski et al., "Factors Controlling CO_2 Exchange on Timescales from Hourly to Decadal at Harvard Forest," *Journal of Geophysical Research-Biogeosciences*, 112, no. G02020 (2007), doi:10.1029/2006JG000293.

11. Hugh M. Raup, "The View from John Sanderson's Farm: A Perspective for the Use of the Land," *Forest History* 10, no.1 (1966): 4. Raup notes: "The major design of the land ownership pattern, here as elsewhere in the town, was laid down in these original surveys and much of it soon became fixed by the construction of stone walls." This perspective is affirmed in David R. Foster, "Lessons from Harvard Forests and Ecologists. IV Three Views from John Sanderson's Woodlot," in *Hemlock: A Forest Giant on the Edge*. (Ed.) David R. Foster et al. (New Haven, CT: Yale University Press): 217.

12. Raup, "The View from John Sanderson's Farm," 6.

13. David R. Foster, "Figure 1. New England Forest Cover and Human Population," in *Wildlands and Woodlands: A Vision for the New England Landscape* (Petersham, MA: Harvard Forest, 2010), 5.

14. Foster, *Wildlands and Woodlands*, 9. The term *hard deforestation* is used to describe 21st century development of suburbs, whereas *soft deforestation* describes deforestation for agriculture in the 1800s.

15. David R. Foster, and Henry David Thoreau, *Thoreau's Country: Journey through a Transformed Landscape* (Cambridge, MA: Harvard University Press, 1999), 135.

16. Foster, *Wildlands and Woodlands*, 4.

17. For a more detailed account of the Earl Stephens study see David R. Foster, "Lessons from Harvard Forests and Ecologists: III The Earl Stephens Plot," in *Hemlock*, 172–80. See also Chadwick Dearing Oliver and Earl P. Stephens, "Reconstruction of a Mixed-Species Forest in Central New England," *Ecology* 58, no. 3 (1977): doi:10.2307/1939005.

18. Foster et al., "The Earl Stephens Plot," *Hemlock*, 178.

19. The age reference for Hemlock in the Prospect Hill Tract is taken from Foster et al., "John Sanderson's Woodlot," in *Hemlock*, 206. Field research of Hemlock mortality and forest species succession is detailed in Foster et al., "Invasion of an Exotic Pest," in *Hemlock*, 129.