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RESEARCH PAPER

A Community Forestry Model Linking Research, Management, Education, and Stakeholder Engagement: Case Study Results from the Town of Weston, Massachusetts, USA

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Abstract Forested land in the eastern United States is owned by a complex mix of public and private owners, often with highly varied objectives and uses. There is an increasing trend at local scales of community forestry programs that use community-based decision making to determine what type of management will occur on town-owned forests. Within the suburban town of Weston, Massachusetts, this type of coordinated approach has been ongoing for nearly 4 decades. This article describes the integration of forest ecology and management research, including a forest inventory and long-term monitoring program, to educate townspeople about their forests, engage students in ecological research, and provide data that the town can use to make informed management decisions. This article presents a novel model for a research-based community forestry program, results from the first inventory and plot measurement period, and describes how other towns can use this type of program to supplement existing active forest management, or provide a baseline for future management. Results are applicable to municipalities that own forest land, as well as land trusts or other private entities that wish to manage their forests using a community based forestry model.

Keywords Community-based forestry · Long-term monitoring · Adaptive management · Citizen science · Environmental education · Wildlands and Woodlands

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Introduction

Community forestry is a model of small-scale forest management[1] with a decentralized approach (Krott et al. 2014) that can be useful in the complex matrix of corporate, non-corporate, and public forest ownership in the eastern United States (Charnley and Poe 2007). Community forestry is often included in definitions of ‘urban forestry’ as well (Konijnendijk et al. 2006); the phrase ‘urban and community forestry’ is common in the literature and in practice. This form of forestry is built on the premise that nearby residents have access to the forest, resources from the forest are sustainably used and provide a benefit to the community, and the community is involved in decisions related to the forest and its resources (Brendler and Carey 1998). The values associated with these community forestry programs vary greatly (Shindler and Cramer 1999; Wollenberg et al. 2001), ranging from local employment through the production of timber and non-timber forest products (Baker and Kusel 2013; Brown 2001; Charnley and Poe 2007; Lyman et al. 2014), to protecting watersheds (Guatam et al. 2002) and mitigating climate change (Charnley et al. 2010). This diversity in community forestry programs is attributed to differing levels of economic development, available forest resources, and community values (Gray et al. 2001).

While these goals are laudable, extensive research has scrutinized the success of community forestry programs in actually achieving them. For instance, a common driving force behind community forestry programs lies in the community-based decision-making process that allows for forest use that reflects the values of the local community, not just those of a single owner (Baker and Kusel 2013; Charnley and Poe 2007; Duinker et al. 1991; Kuser 2007). However, recent studies have questioned whether an entire community is actually involved in this decision-making process (Krott et al. 2014; Molden et al. 2017), while some have even questioned the legitimacy of the term “community” (Flint et al. 2008) in defining the stakeholders involved in community forestry programs. There have been some successful examples of community forestry programs that have involved different stakeholders (Bullock et al. 2009; Danks 2009), but it can be challenging to reach a consensus in a community with diverse values, especially where active forest management is concerned (Beckley 1998; Bullock et al. 2009; Charnley and Poe 2007; Glasmeier and Farrigan 2005; Gray et al. 2008; Teitelbaum 2013). In the more densely settled suburban areas of the eastern United States, the desire to avoid conflict resulting from the active management of forests often results in the passive decision not to do any management at all (Donahue 1999, 2000).

Even if there is a successful and inclusive process by which land-use decisions are made, community forestry organization often struggle to carry out active forms of forest management. In many cases, communities may have an inadequate understanding of the forestry and stewardship practices needed to make decisions regarding the management of their land (Bullock et al. 2009). Community members

[1] We define small-scale forestry after Harrison et al. (2002) as broadly encompassing non-industrial or non-corporate private forests and on parcels whose size can often preclude more intensive harvesting methods (Adlard 2004).

with local ecological knowledge can often help in this process (Ballard et al. 2008), but a lack of funding for the management of community forests and development of new programs often leads to such programs opting for passive land management strategies (Bullock et al. 2009; Gray et al. 2001). Community-based monitoring and citizen science programs have proven to be viable options for community forestry program seeking to learn more about the resource they wish to manage (Bliss et al. 2001; Fernandez-Gimenez et al. 2008). In addition to providing useful data, this community involvement in active management and in forest education is a key component often missing from community forests (Anderson and Horter 2002; Bullock et al. 2009). While community members may be involved in the decision-making process and contribute their knowledge about the resources of the forest, few programs actually involve any significant number of community members in ecological monitoring, harvesting, or stewardship activities (Donahue 2000).

Considering the importance of engaging the community with forestry-related topics, new methods could be implemented that enhance public awareness by involving the community both in the decision-making process and in voluntary participation in forest activities (Gray et al. 2008). Scientific research within community forests is one such opportunity to engage citizens with their woodlands through participatory research programs (Bliss et al. 2001). Citizen science is used as a tool to obtain large amounts of data from multiple locations, and has been implemented to study changes in bird migrations, climate, water quality, and invasive species (Dickinson et al. 2010; Kobori et al. 2015; Silvertown 2009). When applied to forest ecology research, citizen science programs have been used to educate students and other community members about their local ecosystems (Zoellick et al. 2012), while simultaneously providing data that can be effectively used to inform management (Martinez and Alsop 2014; McKinley et al. 2015). These types of programs, which engage community members in forestry activities, can also demonstrate the value of local, sustainable forestry and further garner support for active management (Donahue 2000).

In addition to supporting the active management of community forests, ongoing monitoring and scientific research can allow for the implementation of adaptive management programs (Larson et al. 2013). Without data and records, details of previous management activities can be quickly lost to memory (Nyberg 1999) making it difficult to determine how active management is impacting a community forest. Ecological monitoring, especially over long time frames, is another useful step that can help foster a greater understanding of the ecological effects of different forest uses (Foster et al. 2014). This type of research gives scientific credibility, builds a shared understanding of the resource and the way it is used, and allows community forestry programs to support or defend the management decisions that they make (Fernandez-Gimenez et al. 2008).

Ongoing monitoring also affords land managers the ability to make better adaptive management decisions in line with their goals and values and, if necessary, change the way they are managing their land (Foster et al. 2014).

Objectives

Using the town of Weston, Massachusetts and its community forestry program as a case study, a novel approach to community forestry is presented that includes active management, scientific research, and stakeholder engagement. As discussed, there are examples in the literature of community forestry programs that have successfully used community input to manage a resource (Bullock et al. 2009; Danks 2009; Lyman et al. 2014) as well as examples of research programs that have influenced the management of community forests (Ballard et al. 2008; Fernandez-Gimenez et al. 2008; Stout et al. 2013). However, there are no published examples of community forestry programs whereby members of the community are actively engaged in the both the research and management of their forests. While citizens may have a voice in the decision-making process, their active participation in the various aspects of their community forestry program is often seen as a better measure for the success of that program (Glasmeier and Farrigan 2005).

The interlocking goals of this paper are to (1) present a replicable, low-cost research program whereby community forestry programs can answer ecological questions about the dynamics and long-term development of their forests, (2) demonstrate ways by which the outcomes of the research program can be used in the active and adaptive management of community forests, and (3) demonstrate ways by which community forestry programs can engage local citizens with their forests through the aforementioned research and management programs. We do this by describing the ongoing management and research programs that are underway, and highlight the educational, engagement, and citizen science opportunities that these programs create. The efforts described here are applicable to many forested communities throughout United States, where municipal or other non-profit organizations own or manage significant forested resources. Some examples may be particularly relevant to suburban communities with fragmented forests and where active management may be controversial. Results are also relevant to any community that desires a research-based community forestry program that connects nearby residents with a communally-owned forested area.

Research-Based Community Forestry Model: The Case of Weston, MA

The management, research, and educational programs described in this study take place in the town of Weston, Massachusetts. The research-based community forestry model was constructed based on a wide variety of data sources (Table 1). We, the authors, have been involved in various aspects of Weston's community forest program over 4 decades. Donahue, a long-time resident of Weston, helped to found and directed Land's Sake, the organization that carries out the active forest management, then sat on the town's conservation commission, and has involved his undergraduate students in the ongoing research and management programs described. Lefland oversaw the forest management activities for several years and carried out many of the educational programs described. Huff helped to develop and then carry out much of the inventory and monitoring work. The authors have

Table 1 Data sources to inform the case study and model

Model component	Data source
Forest management	Management plans
	Cutting/harvest plans
	Contracts and stumpage payments
	Conservation commission documents
Educational programs	Curriculum documents
	Contracts and payments
	Personal communication
Research	Primary data
	Management plans
	Interviews with previous forest management personnel

decades of experience working with this community forestry program, from the multiple perspectives of citizen, contractor, researcher, and educator. Where not otherwise noted in Table 1, observations concerning the operation of the program are from the direct personal experience of the authors.

Located only fifteen miles west of downtown Boston, Weston was largely a farming community through the nineteenth century. Following the Civil War many working farms were acquired by wealthy estate owners, leaving most of the landscape still in an agricultural and wooded condition. After World War II much of the town was converted to an affluent residential suburb, even as most remaining farmland was being abandoned to forest. During this period, a coalition of conservationists composed of descendants of estate owners and farmers and newly-arriving commuters formed an early land trust called the Weston Forest and Trail Association, and served on the town's Conservation Commission. Mainly between the 1950s and 1970s this group was able to protect almost one-quarter of the town's farm and forest land, even as it was being rapidly suburbanized. The Conservation Commission, a seven-member town board appointed by the elected Board of Selectmen, serves as the decision-making and management authority for this protected conservation land, most of which is forested. (Donahue 1999; Fox 2002).

Today almost all of Weston is either developed or protected. Of approximately 2000 acres (800 hectares) of conservation land throughout Weston, about 1000 acres (400 hectares) in 7 large parcels are enrolled by the Conservation Commission in a long-term sustainable forest management program, while an additional 200 acres are set aside as a formal wild reserve (Fig. 1). These designations seek to embody the concepts described in the *Wildlands and Woodlands* vision for New England, U.S.A. (Foster et al. 2010) with Woodlands being "well-managed forests of diverse age, species, and structure that are permanently protected…and provide a wide array of economic and environmental benefits" and Wildlands being largely unmanaged but allowing for passive land-use (Faison et al. 2014). The remaining conservation acreage in Weston lies in scattered smaller parcels that have neither been included in active harvesting, nor are formally designated as "wild". Of the 1000 acres eligible for active management, only about 180 acres have actually seen selective

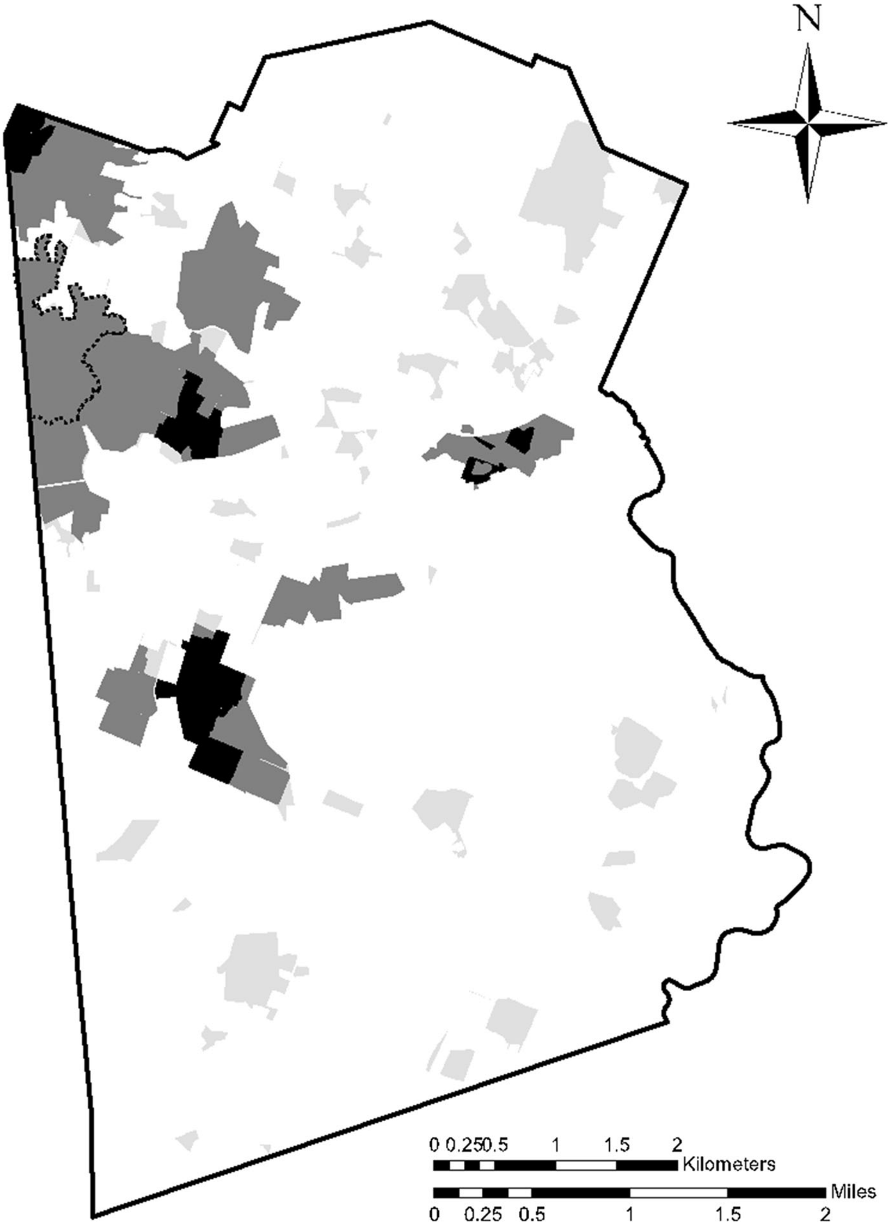

Fig. 1 The town of Weston (outlined in black) owns approximately 2000 acres of conservation land. The study area comprises 1000 acres that are enrolled in a long-term sustainable forest management program (dark grey), including several stands that have been harvested (black). Additionally, the town of Weston has set aside a formal "wild reserve" near the northwest corner of the town (outlined with a dashed black line). The remaining areas of conservation land (light grey) are not part of this study

firewood and timber harvesting over the past 35 years. The town forest is effectively subdivided into several hundred stands averaging five to ten acres in size, many of them demarcated by historic stone walls. Variation in vegetation across these stands reflects different soil types, topography, and above all such historical uses as hay meadows, pastures, woodlots, or tilled fields. However, the exact composition and structure of these stands had never been formally measured and documented prior to the initiation of the research program discussed below.

A Model for Research-Based Community Forestry

The model used for this community forestry effort begins, conceptually, with research. One-time measurement activities (inventory) were simplified for implementation by students or other non-professionals, with supervision and assistance from professionals in the forestry field (Fig. 2a). These one-time activities can then inform ongoing research activities. Forest management activities are also undertaken and are informed by research and in turn form the basis of future research (Fig. 2c). Ongoing research also supports various types of community engagement, which also provides data for research efforts (Fig. 2b). Each stage of the model provides feedback for other stages, in an iterative process.

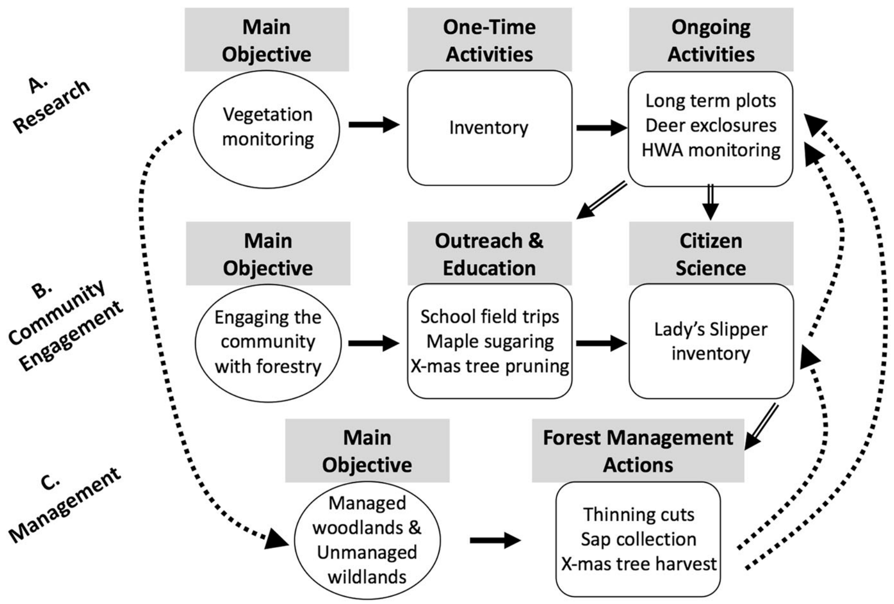

Fig. 2 A research-based community forestry model. This model begins with research (A) whose main objective is to monitor the vegetation on forested land to support management (C). The community is engaged (B) during the research process, during the management process, and feedback is incorporated from management to research in a continuous loop

Long-Term Ecological Monitoring

From 2009 to 2010, the 1200 acres of Wildlands and Woodlands across Weston's town forests were inventoried to better characterize the forest. Initially, several spatial data layers were loaded into ArcGIS from the town of Weston including parcel data, roads, recreational trails, water features, mapped stone walls (incomplete), and land-use data. Using these data, the Weston town forest was divided into 5–10 acre stands based primarily on the location of stone walls, historic land-use, and prior knowledge of the forest.

Within each of these stands, at least one transect was established and a minimum of 50 m was maintained between any two transects. Sampling points were located at the beginning of each transect, and at 25 m intervals along the transect. In stands with multiple transects, a 25 m buffer was maintained between the end of one transect and the beginning of another. At each sampling point, a variable radius plot was measured using an angle gauge with a basal area factor (BAF) of 10. Any "in" trees were identified to the species, and the diameter at breast height (DBH) was measured. Additionally, GPS coordinates and notes about the understory vegetation and tree regeneration were recorded at each sample point. In all, 236 transects with a total of 1193 unique sampling points were established over the 7 largest parcels of town forest described above.

Beginning in 2010, researchers implemented a long-term monitoring program based on the Wildlands and Woodlands Stewardship Science approach (Faison et al. 2014). A stratified random sample of 100 permanent, fixed area plots were located in ArcGIS using forest cover type obtained from the 2009 to 2010 inventory. Five broad forest types were designated based on overstory species composition: white pine, oak, red maple, hemlock, and other (largely consisting of stands dominated by sugar maple, and an old red pine plantation). Plots were 20 $\times$ 20 m and data on tree species, size, status/condition, coarse woody debris, regeneration, and understory vegetation were collected using the methods outlined in Faison et al. (2014).

Forest Management and Non-timber Forest Products

Almost all forestry activities in Weston are carried out by Land's Sake, a community farm and forestry non-profit organization that was founded in 1980 to provide land stewardship and educational services to the town. In most cases, one or two 5–10 acre stands are selected and marked by the town's conservation commission for harvest each year, and a Forest Cutting Plan is filed with the Massachusetts Department of Conservation and Recreation (DCR). The general silvicultural prescription for most hardwood stands includes a combination of selection and thinning, with the goals of improving timber quality in the residual stand while maintaining wildlife habitat, structural diversity, and overall aesthetics. Once a stand is marked and a cutting plan is approved, members of Land's Sake's staff fell and process the low-grade trees using chainsaws and a tractor mounted, power take-off (PTO) mounted skidding winch. From there, the wood is split by a hydraulic splitter or by volunteers by hand (described later) and stacked in the forest so that it can season over the summer before delivery in the fall. Approximately

5–10 cords per acre are removed, typically amounting to 50 cords per year. On a few occasions, pine and oak sawlogs have been harvested and sold, and local woodworkers have purchased small amounts of material for use in personal projects. Many stands have been treated twice since this program started in the 1980s (Donahue 1999), and are at the point where regeneration treatments could be implemented. In addition to forestry work, Land's Sake is responsible for bringing community members into the woods before, during, and after harvesting operations to address any concerns they may have about the work. In addition to forestry work, Land's Sake is responsible for bringing community members into the woods before, during, and after harvesting operations to address any concerns they may have about the work.

Land's Sake is also responsible for the production of non-timber forest products (NTFPs) in the form of Christmas trees and maple syrup. Christmas trees are grown on conservation land, in areas that the town wishes to maintain as open field. This program allows for the maintenance of the field, and for the production of locally grown Christmas trees that community members can purchase. Maple syrup is also produced on town conservation land. Sap buckets are installed in sugar-bushes that have been improved through past firewood harvests, and boiled in a town-owned sugar house near the Weston Middle School. Both of these programs are run by Land's Sake staff with help from volunteers and students (described later).

Educational Programming, Stakeholder Engagement, and Citizen Science

Land's Sake and the Weston Conservation Commission have engaged in efforts to educate and involve students and community members in active forest management since the beginning of the community forest program (Table 2). As previously described, informational forestry walks for neighbors and interested townspeople are offered before, during, and after harvesting. The guiding principle has been to engage as wide an audience as possible with timber harvesting, rather than trying to hide harvesting activities for fear of backlash. Additionally, Land's Sake leads volunteer work days where community members can assist with many aspects of the program including splitting firewood, collecting sap for maple sugaring, and pruning Christmas trees. Monthly forest walks sponsored by the Forest and Trail Association sometimes serve as additional venues to tour and discuss past and present harvesting sites. Weston has also played host to forest walks and events organized by wider regional groups, such as a community forestry outreach event sponsored by the Massachusetts DCR Forest Stewardship program.

From the earliest days, Land's Sake worked with biology and environmental science teachers at Weston High School to establish course curriculum units on forest conservation and stewardship, including tours of logging sites in the town forest. In 2007, a new element of active ecological research was introduced when the Conservation Commission began to collaborate with the Brandeis University Environmental Studies program on projects including the long-term forest monitoring work described later in this paper. This relationship has proven especially useful in recent years as the conservation commission embarked on a program to treat Hemlock Woolly Adelgid, and on another to introduce bow hunting

Table 2 Participation in research and forestry activities from the 1970s to the present day

Activity	Year started	Overseeing organization[a]	Participant demographic	Number of participants (annually)
Research				
Forest inventory	2009	BU and CC	College students	1–2
Long-term plots	2010	BU and CC	College and high school students	5–10
Deer exclosures	2012	BU, HF, CC	College and high school students	40–50
Hemlock woolly adelgid monitoring	2008	BU, HF, CC	High school students	40–50
Lady's slipper census	2013	BU, HF, CC	Adult garden club members	7–15
Forestry				
Timber and firewood harvesting	1981	LS and CC	Staff	2–3
Wood splitting and stacking	1981	LS	All ages, town residents	25–50
Maple syrup production	1973	LS and CC	Staff	2–3
Maple sugaring education program	1973	LS	Middle school students	10–15
Volunteer sap collection	1973	LS	All ages	25–50
Field trips to sugar house	1973	LS	Pre-K through middle school	100 +
Christmas tree harvesting, maintenance, and pruning	1990	LS and CC	Staff and all ages for pruning	15–20

[a] *BU* Brandeis University, *CC* Weston Conservation Commission, *HF* Harvard Forest, *LS* Land's Sake

to town lands to control the increasing deer population. Brandeis faculty and students helped map hemlock stands, install long-term monitoring plots, and construct deer exclosures to provide empirical data about the implementation of these programs. Land's Sake then modified its forest programs with Weston High School to involve younger students in annual inventories of these plots. Weston's conservation commission also initiated a citizen science program whereby members of the Weston Garden Club help conduct annual inventories of lady's slippers along forest trails, providing another index of long-term change on the impact of browsing deer. Much of this work is now being carried on through an additional partnership between Brandeis and Harvard Forest, adding another set of research assets.

Baseline Ecological Research Results

Inventory

The initial inventory conducted in 2009 had two main goals. The first goal was to delineate stands for future management and research, and the second goal was to quantify the number, area, and density of stems within each stand so that the stand could be classified into a forest-type category. Using this method, it was possible to obtain a very detailed record of the overstory tree species composition of each stand, and create stand tables similar to those obtained from a traditional timber cruise. Because multiple points along (sometimes) multiple transects were sampled within one stand, very accurate measures of species composition, mean diameters, and basal areas could be determined. The fine resolution of this data allowed for the appropriate categorization of each stand and ensured that the subsequent long-term monitoring had an accurate starting point. Additionally, this data informed a detailed forest inventory database which could be mapped (Fig. 3) and used by the town and organizations such as Land's Sake that manage town land.

Plot Results

The observations made at the 100 long-term monitoring plots include measures of regeneration, understory cover, canopy structure, and non-living material. Because the plots are aggregated into forest stand types, it was possible to examine the differences between and among these types, and set a baseline for future research (Table 3).

Preliminary analysis of this data was done in R (R Core Team 2014) by creating a series of boxplots to examine differences in the mean values of a number of measured variables across the different forest stand types (Fig. 4). These structural and ecological attributes demonstrate and quantify the variation across the forest types, but also within each forest type. For example, the basal area of hemlock stands (58.6 m^2/ha) is higher than any of the other forest types. However, there is significant variation within each of those hemlock stands, likely due to past management, site indices, soil types, or past disturbances. There are other informative trends, such as the variation in the number of saplings in white pine stands, and the relative uniformity of the understory species richness across all of the different forest types.

To further analyze the differences across the different forest types, a series of ANOVAs and post hoc Tukey honest significant difference (HSD) tests were conducted to determine significant differences in the mean values for a number of variables across each forest type. Hemlock stands had significantly different basal areas than oak stands, red maple stands, and other stands ($p < 0.001$, Table 3). White pine stands and red maple stands also had significantly different basal areas ($p = 0.0011$).

Discussion

Evaluation of the Ecological Inventory and Long Term Monitoring Plots

There are differences in the depth and breadth of the two sampling methodologies used in this research program; the forest inventory is designed to capture different information than the long-term monitoring plots and may be more appropriate for

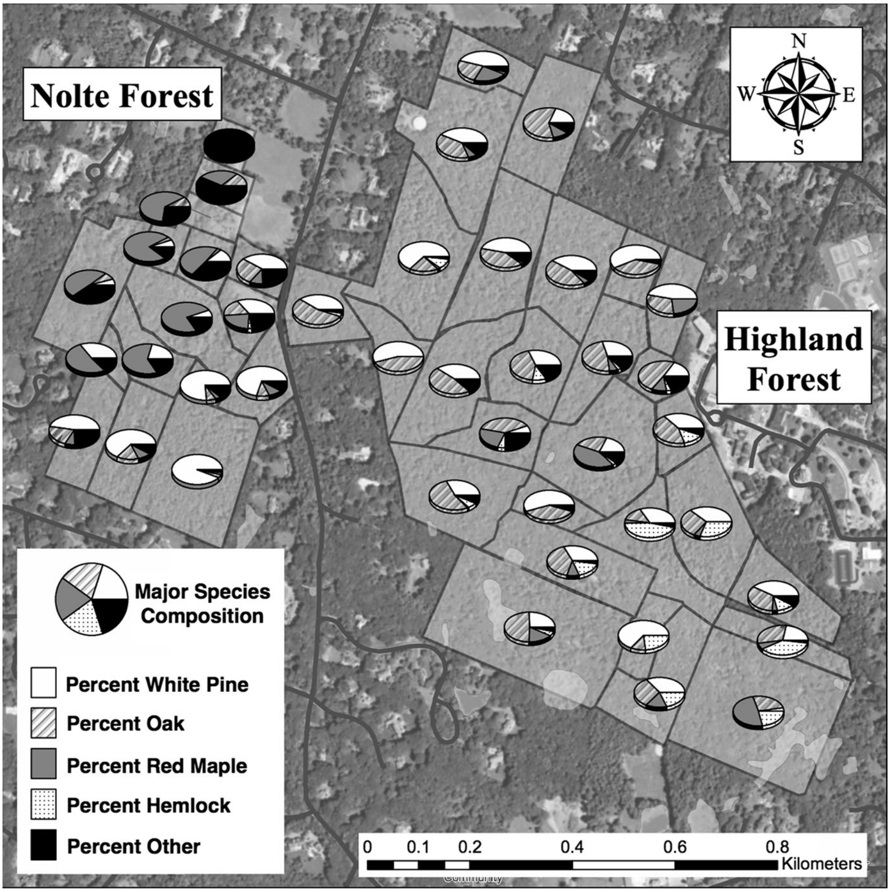

Fig. 3 Maps that are useful to land managers and conservation organizations can be created using the data obtained from a forest inventory. This map shows the boundaries of each stand in two parcels of forest (Nolte and Highland), and the overstory species composition of those stands

towns with fewer resources for forestry. The inventory method is akin to a timber cruise in that it provides stand-level details about species composition, basal area, and regeneration. This inventory can be undertaken by non-professionals, with some supervision and training identifying and measuring trees. Multiple sampling points within each stand ensured that a large percentage of the stand was being sampled, and that both means and variation of measured variables could be determined. Having such a detailed inventory allows for better land management, especially when rotationally managing small parcels of forest, as is done in Weston. While this type of inventory is useful and efficient in determining the composition of multiple stands across a forest, it is clear that many biotic and abiotic factors went unmeasured, and that this methodology would not be very useful in determining long-term forest dynamics.

Table 3 A sample of the summarized data obtained using the long-term monitoring methodology by forest stand type

	Hemlock	Oak	Other	Red maple	White pine
Total area (hectares)	6.07	123.91	12.30	137.31	215.67
Percent of forestland	1.2%	25%	2.5%	27.7%	43.5%
Number of plots[a]	5	25	5	22	43
Number of wildland/woodland plots	0/5	2/23	0/5	6/16	7/36
Density (trees per hectare)	515	461	370	367	435
Mean DBH (cm), standard error in parentheses	36.36 (3.3)	28.81 (0.84)	31.14 (2.10)	29.40 (1.36)	33.14 (0.75)
Mean basal area (m^2/ha), variance in parentheses	58.59 (14.91)*	37.49 (10.24)*	31.01 (5.49)*	32.61 (14.27)*	45.72 (12.96)*
Mean basal area of snags (m^2/ha), standard error in parentheses	3.86 (6.67)	1.77 (2.05)	4.69 (2.45)	2.80 (3.04)	3.36 (1.98)
Mean coarse woody debris volume (m^3/ha), standard error in parentheses	37.88 (0.90)	19.33 (0.13)	49.99 (0.82)	16.84 (0.09)	33.38 (0.20)
Understory species (average number of species per plot)	14.8*	18.5	20.6*	20.9	19.0
Understory flowering plant richness	1.8*	3.2	5.4*	3.9	3.3
Saplings per ha, variance in parenthesis	1030 (1391)	1262 (1122)	515 (320)	668 (777)	1335 (1386)

*Denotes significant differences across forest types with a threshold of $p < 0.05$

[a]Additional hemlock plots were installed for a hemlock-specific study and one red maple plot was covered by water between installation and measurement

Observations taken at the 100 long-term monitoring plots were more detailed than the inventory data. Because there are many fewer long-term plots than inventory sampling points (100 compared to 1193), the number of observations and measurements at these plots is significantly greater, and provide important details about forest health, succession, regeneration, structure, and habitat. In contrast with the inventory, observations from the long-term monitoring plots included measures of standing and fallen dead wood, detailed measures of understory species composition, and observations of overstory trees. These data provide insight as to how broad forest types are changing within the study area, not at the level of individual stands. The long-term plots also have an extremely high educational value because of their adaptability and use in adaptive management decisions (discussed below), and once established, there is little effort required to maintain them.

In addition to serving as baseline data for long-term ecological changes, the long-term monitoring plots also allow for further study into the effects of forest management, and deer population control, and can be used as baseline data when designing future experiments (Faison et al. 2014). Because the town of Weston has designated certain portions of the forest as either wildland or woodland, plots in unmanaged wildlands can be used as a control when examining the impacts of forest management on woodland areas. This experimental design allows for the

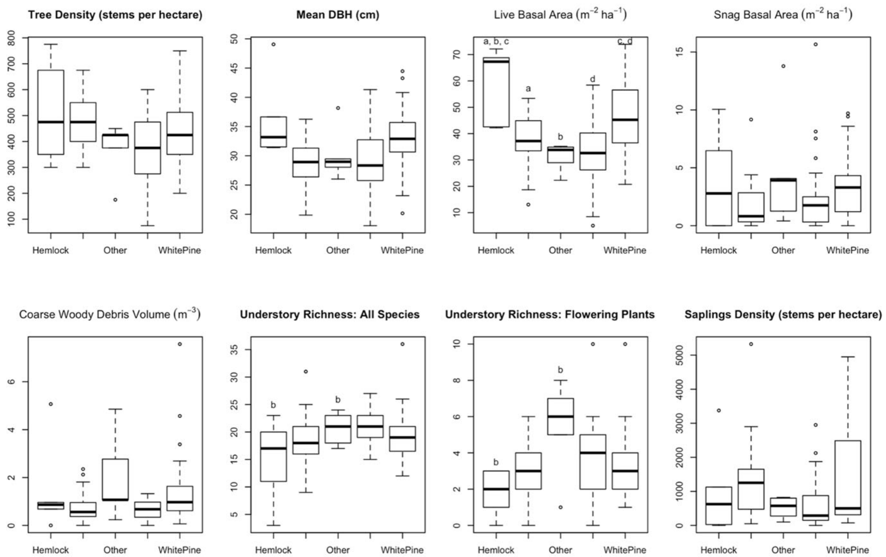

Fig. 4 Box plots show the variation across and within the different forest categories for a number of measured variables. Lettering signifies a significant ($p < 0.05$) result from post hoc Tukey comparisons between two forest types; a: hemlock/oak; b: hemlock/other; c: hemlock/white pine; d: hemlock/red maple

examination of rates of forest succession, forest structure, habitat, biomass sequestration, and more, and links these changes to forest management. For example, Weston implemented a research program to examine the impacts of deer hunting on forest regeneration and succession. Any of the 100 plots can be used as a control for a matched or neighboring deer exclosure, and this type of project has already been implemented using 10 exclosures around the town of Weston. Similar programs have used community engagement and research to inform adaptive management of deer populations with great success (Stout et al. 2013). The flexibility within Weston's program allows for the implementation of new studies to examine different forest uses management decisions, and ultimately leads to the ability to make adaptive management decisions.

Evaluating the Community Forestry Model in Weston

Weston's community forest experience demonstrates the long-term success of an approach that includes multiple stakeholders and combines management, community engagement, and research. As a municipal landowner, the Weston Conservation Commission ultimately makes decisions, but two community-based non-profits (Land's Sake and the Weston Forest and Trail Association), the local public school system, and two university programs (Brandeis Environmental Studies and Harvard Forest) are also invested in various aspects of the forest program, providing continuity and a source of new projects.

In Weston's case, forest management was the initial objective of the program, with firewood harvesting initiated in 1981, and maple sugaring begun in 1973 (although tapping was initially confined to roadside trees before moving into the woods and onto conservation land). However, the long survival of the program depends upon community engagement, and in turn education is the leading outcome of the program—far surpassing the modest output of cordwood and syrup. From the start, youth were involved collecting and boiling sap, and splitting and stacking firewood. Beyond the direct benefits to the participants, this served to soften and humanize the disturbance imposed by wood harvesting in a suburban setting. The products are also sold to residents of Weston and neighboring communities who value locally produced firewood, timber, syrup, and Christmas trees—especially if they or their children have had a hand in the production. In time, a wide range of school programs were added, and more recently Brandeis University undergraduates have become involved. Several of these students (including two of the authors of this paper) have gone on to work in various aspects of the Weston forest program, and to careers in forestry.

The longevity of the program is perhaps best explained by its deliberate approach to engaging neighbors and citizens at large—and as time has passed, that longevity itself has become an asset. The Conservation Commission and Land's Sake inform neighbors before harvesting is undertaken, and invite them to a preliminary site walk. These walks frequently pass through stands that have been previously cut, sometimes going back decades. This usually brings comfort to new residents who are unfamiliar with harvesting. From time to time, someone who encounters harvesting will initially object, but so far (36 years) walks, conversations, and willingness to compromise (sparing a favorite tree, adding an extra buffer along a property line) have been able to satisfy these concerns. Deeply embedded support for the program on town boards and familiarity among long-time residents tends to dampen the resonance of alarms that are occasionally raised. While a town-wide survey evaluating the support for this program was not conducted, it is important to note that the Conservation Commission is a town board that manages the land on behalf of the community. The commission would not be able to impose its will on friends and neighbors if there were broad disapproval, and the elected Selectmen (who appoint the members of the conservation commission) would overrule them. Ultimately the decisions of the conservation commission are answerable to direct democracy via town meeting, and reflect the town's support for the active management of their forests.

Since the research program is relatively new and aimed mostly at long-term monitoring, so far there are only baseline scientific results to report. Research feedback into management decisions is also at an early stage. The Conservation Commission and Land's Sake have been able to use the stand inventories in planning upcoming harvests. Whether information from the long-term plots will influence future management choices remains to be seen. In the case of hemlock woolly adelgid, research plots were established at the same time as initial treatments, and it is likely that the Conservation Commission will consult data from the plots in deciding about follow-up treatments. In the case of deer population management, scientific browse studies were not used to inform the decision to introduce bow-hunting, although several experienced wildlife biologists and botanists were consulted for their opinions. However, the exclosures and research plots that were established as hunting was introduced are likely to play a role in guiding the future direction of the program. The mixed citizen science approach to forestry research used here involves trade-offs between data quality and resource efficiency. For example, citizen science data collected in an urban forestry context indicated systematic bias (Roman et al. 2017). However, the trade-off is allowable for the gains in stakeholder engagement and overall community support for forests (Cooper et al. 2007; Dickinson et al. 2010).

Beyond this, the presence of education and research plays a subtler role in the politics of management decisions at the community level. Introducing bow-hunting in this suburban community proved controversial, not surprisingly. However, a proposal to ban hunting was rejected by citizens at town meeting. Several remarked to one of the authors (who was present at the meeting) that they were reassured by the research effort that was to accompany the hunting program, or that they were confident in the Conservation Commission's ability to work through a complicated issue, or even that they had mixed feelings about bow-hunting but were there simply to support the Commission. This suggests what the strong vote confirmed—that a patient, multi-stakeholder approach to community forestry can build and maintain support for active management that is sometimes difficult and controversial, such as harvesting trees and hunting deer.

Broader Applicability of Research-Based Community Forestry Programs

Across New England, there are other examples of community forestry programs that engage community members in decision making, and often employ local people through forest management activities (Lyman 2007; Lyman et al. 2013; Northern Forest Center 2017). These programs already have ongoing active management and various elements of community engagement, so implementing a research component could be seen as the next logical step towards growing the community forestry program. As described earlier, supplementing an existing community forestry program with a long-term monitoring program can be an excellent way to further involve the community, and to inform adaptive forest management. The major challenge that these community forests may face in attempting to integrate a research program lies in finding a host institution (or institutions) that will be responsible for the program (Bliss et al. 2001). In the case of Weston, partnerships between a local university, the town high school, and the town's conservation commission were largely what allowed for the sustainability of the program. Facilitated by the conservation commission, the educators from both the high school and university used the long-term monitoring plots to provide their student with hands-on educational experiences, and took ownership of the data collection and management. By designing a research program around the existing institutions in a town, it is possible to achieve both the educational and data-collection goals associated with such a program (Lyman et al. 2013).

In towns where active forest management is not already underway, developing a community forestry program which entails active forest management can be challenging. Harvesting timber may be a foreign concept for community members who have not been exposed to forestry, and opposition towards cutting trees may arise from townspeople who believe that conservation land should be preserved and not managed (Donahue 2000). Demographic characteristics including income, education, and political leaning can have a significant impact on the public's attitude towards timber harvesting (Schaff et al. 2006), so towns wishing to engage in active forest management need to understand the attitudes of the community before taking any action. Implementing a research program can serve as a starting point to educate citizens about local resources, and as a catalyst for developing a forest management program. In the case of the Desert Natural Area in the towns of Sudbury, Hudson, and Marlborough, MA, the restoration of fire-dependent ecosystems through research and active forest management has gained supported from community members (Sudbury Valley Trustees 2017). Initially, the results of a research program were used to develop a management plan for the area, and to educate local citizens about the stewardship and management needed for habitat restoration. Fueled by the community's strong environmental convictions and the results of this initial research, management in the form of prescribed burning and selective timber harvesting has been implemented. Other communities could adapt this approach and create a research program that educates community members about their natural resources, and how those resources can be managed. This outreach then creates support for active management when the community is ready to implement such a program.

Other factors, including economic and social motivations, may help increase the appeal of timber harvesting through community forestry programs. Newman and Wear (1993) showed that private landowners tend to value standing timber over the revenue generated from a harvest. However, these same landowners may be swayed to harvest their forest if there is a large enough economic incentive. In the case of community forests, increased oil and gas prices may prove to be sufficient to begin harvesting firewood as an alternative source of energy. Social motivations can also provide an incentive to harvest timber, as was seen in the case of the Walden Pond State Reservation in Concord, MA. Though not affiliated with a community forestry program, the famous reservation made the decision to harvest 25% of the building materials for its new visitor center from the local woodlands once inhabited by Henry David Thoreau. Similar social motivations, such as the increase in popularity of timber-framed construction or a desire to buy locally sourced wood products, would surely further support for the active management of community-owned forests.

Although this model has worked very well for Weston—as measured by the sustainability of all programs and research efforts, annual participants, and receptiveness of town residents—it will need to be validated via additional case studies throughout New England and through continued evaluation in Weston. Efforts are underway to use this model at the Walden Woods of Concord and Lincoln Massachusetts, the Blue Hills Foundation in New Hampshire, the Merck Family Forest in Rupert, Vermont, and in conjunction with Highstead and the town of Redding, Connecticut. In-depth qualitative research (e.g., interviews with model implementers) will be an important next step.

Conclusion

Community forestry is a unique model by which citizens can be involved in the decision making-process for the use and management of town-owned forests. Different values and beliefs must be reconciled in order for a community forest to function properly, especially when active management of forest land is being considered. Town boards, especially in suburban areas, may be hesitant to manage their town forests for fear of push back from citizens. However, the addition of a strong woodland science program can inform townspeople of the benefits of forest management, and increase confidence that scientific data is being used to inform adaptive management decisions. These monitoring and research programs have a very high educational value, even if the amount of active management is relatively small. As conservation efforts steadily bring some degree of community ownership and interest to an increasing portion of the forests of New England and similar regions, robust community forest programs that include active management, research, and education may be crucial element in promoting sustainable stewardship of the forest as a whole.

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