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MANAGING TREES ON CAMPUS:

A SURVEY OF NORTH AMERICAN COLLEGE AND UNIVERSITY TREE CARE PRACTICES AND OPERATIONS

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About this Report

In this report are the results of a survey study conducted in 2017 and 2018 by scholars from James Madison University. The survey was developed by Dr. Mikaela Schmitt-Harsh, with input provided by faculty and staff from James Madison University and Indiana University. This report has not been peer-reviewed and should not be quoted or cited without permission of the principal investigator.

The survey was distributed to institutions across the United States and Canada, with the assistance of the Arbor Day Foundation and APPA - Leadership in Educational Facilities. Prior to distributing the survey, the principal investigator submitted an application to the Institutional Review Board for consideration. The study and corresponding survey was exempt from oversight of the Institutional Review Board of James Madison University. Questions about the survey should be directed to the principal investigator. The authors thank Amber Morrison, Program Operations Manager at the Arbor Day Foundation, and Steve Glazner, Director of Knowledge Management at APPA, for their support of this project and assistance in distributing the survey.

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Executive Summary

In 2017 and 2018, a study was conducted to better understand the extent to which college and university campuses are treed and how trees are managed. A web-based survey was administered to North American institutions of higher education using three alternative approaches. The first was an email blast from the Arbor Day Foundation to all institutions certified as Tree Campus USA. The second consisted of directed emails to institutions that were identified using a stratified random sampling approach from the Carnegie Classification of Institutions of Higher Education system. The third consisted of an email blast to institutional members of APPA, Leadership in Facilities Management. Use of these three approaches aimed to solicit feedback from as wide of a network of colleges and universities around the United States and Canada as possible, including institutions with established tree management plans and institutions that lack a formally recognized tree management program. Individuals contacted to participate in the survey included campus arborists and facilities staff members who are active in campus tree management efforts.

We received 378 responses to the survey (response rate indeterminate given sampling approach). Institutions in each of the 50 states and Washington, D.C., with the exclusion of Delaware, participated in the survey, with some states having almost 30 participating institutions. Twelve of the responding institutions were from Canada, representing four Provinces and one territory. The majority of respondents were from 4-year public institutions (n=200) and 4-year private not-for-profit institutions (n=142), with a small number of respondents from 2-year public institutions (n=36). A number of colleges with active Tree Campus USA certification responded to the survey (n=138, 36%), though the majority of respondents do not currently take part in the program (n=240, 64%).

Trees are a recognized and significant asset to colleges and universities. For trees to remain an asset and to increase in value, they require care and regular maintenance. This report shows how institutions are managing their trees on average, and estimates the extent to which college campuses are treed. This is the first survey study that we know of that focuses specifically on the college campus forest landscape.

A few highlights from this study include:

- Respondents of this survey study were diverse in their stated tree abundance. The majority of respondents indicated having somewhere between 1,000 to 5,000 trees, though estimates ranged from 10 trees to 50,000 trees. Most respondents indicated their tree abundance value was an estimate rather than an accurate account.
- Currently, 36% of responding institutions either have a tree planting goal (20%) or are developing one (16%). The frequency was higher for four-year public institutions than for four-year private and two-year public institutions.
- Two-thirds of the responding institutions (67%) indicated they have some level of a tree inventory, with just over 50% of these computerized. The software used to collect and track inventory data varied; the most common responses included Microsoft Excel, ArcGIS, ArborPro, and ArborScope.
- Tree inventories regularly included information about tree species (99%), tree location (97%), tree diameter (69%), and tree condition (69%). Other information, such as insect/disease problems, tree conflicts, height, tree risks, year planted, and tree value were also collected by some institutions.
- Inventories were used for directing work, such as identifying tree planting locations (72%), selecting tree species to plant (69%), removing trees (62%), and scheduling tree pruning (55%).

- In terms of the major expenditures associated with tree care and maintenance, three major work activities dominate: planting, pruning, and tree removal, including the disposal of trees. Closely following these three was the cleanup of tree debris associated with storm damage.
- The most commonly cited reason for trees to be planted was aesthetics. Two other common reasons include improved health of students and personnel, and educational opportunities for students.
- Reasons for tree removal included tree death or decline (100%), disease/insect problems (84%), conflict with a development project (82%), and storm damage (79%), among others.
- After removal, trees may be disposed of in many ways. Over three-fourths of all respondents create mulch from campus trees (78%). Other common disposal methods included production of firewood (41%), disposal in a landfill (25%), and re-use of lumber for on- or off-campus projects (23%).
- Is the current budget adequate to meet identified needs of current or projected future tree care goals? Roughly equal numbers of respondents indicated the budget was adequate (50%) and *not* adequate (50%).
- When asked to rate their satisfaction with the budget for tree-related work, over half of all respondents indicated they were satisfied (43%) or very satisfied (10%). Just over 30% of all respondents indicated they were unsatisfied (27%) or very unsatisfied (5%) with their budget.
- Paralleling the lack of satisfaction with the tree-care budget for some institutions, was identification of (the lack of) funding and resources (56%) as a major weakness of the institution's tree care program. The other most common weakness identified by respondents included limited staff (66%).
- The three most common strengths identified by respondents included the institution's diversity of campus tree species (72%), quality of tree care (55%), and extent of tree canopy (50%), staffing expertise in tree care and management (39%) and contractor performance/relationship (38%).

Introduction

Trees on college and university campuses hold considerable aesthetic and environmental value. In fact, some campuses are defined by their canopy of trees, their stately old landmark trees, and their unusual specimens. Trees and their associated habitat provide space for classroom exploration, undergraduate research opportunities, and recreation. They also provide a number of ecosystem services that make campuses more livable, including control of noise pollution, control of wind and water erosion, shade and associated cooling, uptake of atmospheric pollutants, and provision of habitat for birds and other animals.

The 4,600-plus colleges and universities in the U.S. and Canada offer ideal places to showcase efforts to beautify and manage landscapes sustainably. How treed are these landscapes? Are these landscapes being managed sustainably and systematically? Are the campus departments who are responsible for tree care and management adequately staffed and financially supported? To our knowledge, no research has been conducted to understand the extent to which colleges and universities are treed, and the ways in which institutions manage their trees. In contrast, national longitudinal studies that collect information on *municipal* tree care and management have been conducted since the 1970s; these datasets provide useful data to benchmark and track future progress. The first study was conducted in 1974 by Ottman and Kielbaso (1976) and additional assessments were conducted in 1980 (Giedraitis and Kielbaso 1982), 1986 (Kielbaso *et al.* 1988), and 1993 (Tschantz and Sacamano 1993), with the most recent baseline assessment of municipal tree programs occurring in 2014 (Hauer and Peterson 2016). Against this backdrop, we sought to gather information from North American colleges and universities to learn more about the goals and operations of campus forestry programs. We developed an institutional survey that incorporated ideas and design elements from the survey studies highlighted above. Such studies aided our understanding of municipal forestry trends, and provided a good starting point from which to tailor our survey to the college landscape.

Study Goals and Objectives

The goal of this study was to better understand the extent to which college and university campuses are treed and how trees are managed. Specific objectives of this survey were to:

- Estimate the number of trees and the extent of tree canopies on campuses.
- Characterize the strategies employed by institutions to manage trees on campus.
- Characterize the key personnel involved in setting tree care rules and strategies, and the stakeholders involved in cooperating in the strategies.
- Examine the perceptions of institutions regarding their strengths and weaknesses as they relate to their tree management program.

For our purposes, the term "tree management program" refers to all services and activities taken by the institution to manage and maintain campus trees. Such activities or efforts may include, but are not limited to, planning, planting, inventorying, pruning, watering, fertilizing, controlling pests, removing trees, and other tree maintenance activities. Campus trees occur in open "quad" spaces, in gardens, along streams, in "wild" areas within campus boundaries, in "wild" areas located beyond the borders of the main campus, and in designated arboretums.

The collection of all campus trees, from the individual trees in open quad spaces to the trees in "wild" areas located beyond the borders of the main campus, constitute our definition of the "campus forest". This definition draws many parallels to the definition of "urban forest", as being all publicly and privately owned tree within an urban area, including trees along streets, in backyards, and in stands of remnant forest

(Nowak *et al.* 2001). In many ways similar to urban forestry, the key to defining campus forests lies in delimiting the spatial extent of campus. The term "campus" generally includes areas that are owned and operationally managed by the university, including the space used for libraries, residence halls, classrooms and laboratories, student centers or dining halls, athletic fields, gardens and other green spaces. In some cases, land may be owned and operationally managed by the university but located a far ways from the campus center (e.g., experimental stations, off-campus residential areas).

We were inclusive in our definition of "campus forest" though recognize that distinguishing trees located, for example, in highly managed as opposed to wild or even experimental spaces may impact the efforts employed to maintain such trees. Further, we did not distinguish trees in arboretums from trees in the campus landscape as a whole. Ideally our survey efforts would enable us to parse out tree management activities on the more constructed areas of campus from the natural areas, but this proved to be challenging. A number of colleges and universities consider their entire campus to be an arboretum due to an extensive and diverse tree canopy. For example, the 400-acre campus of the University of Arizona (Tucson, AZ), the 100-acre campus of Agnes Scott College (Decatur, GA), and the 92-acre lower campus of the California University of Pennsylvania (California, PA) are regarded as whole-campus arboretums (Jones *et al.* 2015). Others, like the 45-acre University of Idaho Arboretum and Botanical Garden (Moscow, ID) and the 125-acre Edith J. Carrier Arboretum at James Madison University (Harrisonburg, VA) are on-campus arboretums that are operationally distinct from the main university campus. And yet other institutions manage large numbers of planted trees, some natural woodlands, but do not formally register such areas as arboreta (per the Morton Register of Arboreta, see http://arbnet.org/). We discuss some of the limitations of our survey instrument and the complexities we experienced in defining "campus trees" in the Conclusions and Recommendations section.

Broader Impacts

This study targets a topic that directly affects the management and sustainability of campus forest ecosystems. In particular, information from this study will lend insight on the self-reported strengths, weaknesses, and opportunities of campus tree management programs. This report can be used by college facilities departments and arborists to inform decision-making processes on tree care and forestry practices.

Background

The College Campus as a Sylvan, Landscaped Park

In the book *Campus: An American Planning Tradition,* Turner (1984) argues that the college campus is a uniquely American type of landscape. Whereas many European universities are located in cities, universities and colleges in the U.S. are often located in rural settings. Here, trees figure prominently in creating a natural aesthetic that is reminiscent of rural and less developed lands. So romanticized is this notion, that schools located in urban areas often go to considerable lengths to be green and wooded (Gumprecht 2007; Roman *et al.* 2017). For example, the University of Oklahoma's first president is often remembered more for his tree-planting efforts than for building the university into a respected institution (Gumprecht 2007). Long before a single faculty member was hired or construction on the university's first buildings began, trees were planted on University grounds. Over the years, the Oklahoma campus, located in the 3rd largest city in Oklahoma, has become one of the most popular public spaces in the region.

Many college campuses are also intentionally designed as extroverted and expansive spaces that provide a number of learning and recreational opportunities for the surrounding community. In more urban areas, these open spaces are often highly valued by surrounding residents. For example, a resident of Newark, Delaware commented that without the University of Delaware campus "there would be no park" in the city (Gumprecht 2007, 86). Designated campus spaces for gardens and arboreta also draw substantial public interest and provide a number of recreational, research, and educational opportunities. The Botanical Gardens at the University of Rhode Island (Kingston, RI), for example, hosts about 3,000 visitors each year including school children (Jones *et al.* 2015). The 92-acre Morris Arboretum of the University of Pennsylvania, home to over 12,000 labeled plants, provides research and outreach services to state agencies and community institutions, and provides a number of classes, tours, lectures, and activities to engage with community members of all ages. There are countless other examples of remarkable campus arboretums and gardens, their diverse assemblage of plants, and the educational services they provide to students, faculty, and the community. In many cases, access to campus spaces and educational opportunities is free to the public despite substantial operational costs borne by the university (Gumprecht 2007), underscoring the importance that many universities place on building connections and being an integral part of the town or city surrounding the campus.

Sustainability has increasingly become an important principle for college campuses (Jones *et al.* 2015). Programs and organizations such as the National Wildlife Federation's (NWF's) *Campus Ecology Program,* which began in 1989, and the American Association of Sustainability in Higher Education (AASHE) work to advance higher education leadership, curriculum development, and student expertise in biodiversity, climate action, and sustainability. Other programs, such as the NWF's *National Campus Environmental Report Card* and AASHE's Sustainability Tracking, Assessment & Rating System (STARS) provide colleges with frameworks to assess, track, and measure sustainability performance. And there are yet other initiatives and publication opportunities, such as the *Campus Sustainability Case Studies* database and the NWF's *EcoLeaders Initiative,* that offer students and other campus leaders the space to create, share, and be recognized for their leadership efforts in sustainability.

Tree planting initiatives represent one part, and certainly an important part, of the sustainability trend (Roman *et al.* 2017). Certification programs, such as the Arbor Day Foundation's Tree Campus USA, highlight campus tree care efforts by recognizing colleges and universities that effectively manage their trees, engage the campus community in tree maintenance, and educate the campus and broader community on the importance of trees. In its first year (2008) of the award, 29 campuses earned the designation of "Tree

Campus USA" (see https://wmich.edu/facilities/landscape/beautification). By 2018, the number of certified universities and colleges had increased to 369.[1]

Perhaps in part associated with the Tree Campus program, many colleges are setting targets for tree cover or tree canopy (for example, Georgia Institute of Technology 2014; Portland State University n.d.; Washington University in St. Louis 2015), and there are now many examples of student- and faculty/staff-led projects to inventory trees and quantify their ecological value (for example, Auburn University 2011; Southern Methodist University 2013; University of Arizona 2012; University of California San Diego 2009; University of Pennsylvania 2015). Similar to trends experienced in municipalities, it's becoming more common for universities to develop active tree management plans and employ staff that are certified arborists.

The campus as a sylvan landscape provides a number of research opportunities for faculty and students, including studies focused on plant-pollinator dynamics, plant-animal interactions, invasion ecology, restoration ecology, plant genomics, and arboriculture. Treating the university grounds as an experimental landscape has resulted in studies about dendrochronology (Copenheaver *et al.* 2014), inventory design (Martin *et al.* 2013), and forest change over time (Roman *et al.* 2017). In connection with efforts by students and other university leaders to investigate campus forest dynamics, such as canopy cover and ecosystem services, the college campus is increasingly embedded within the larger urban forestry discourse.

Benefits of Trees to Human Health and Wellbeing

While the extent to which campuses are treed may be partially due to land availability and the notion that green, wooded landscapes are aesthetically beautiful, there is also increased research that demonstrates the (mostly positive) impacts of trees and other green infrastructure on human health and wellbeing. In fact, the past years have seen a rapid rise in both experimental and observational research that examines the relationship between trees and other green infrastructure on human and ecological health. Much of this work focuses on urban and peri-urban landscapes and Tzoulas *et al.* (2007) provides a good overview of such research. It's worth noting that much of this work aggregates trees with other types of natural spaces, which may also be termed "greenspaces" or "green infrastructure", depending on source and author. A review of these terms can be found in Benton-Short *et al.* (2017), Escobedo *et al.* (2019), and Wang and Banzhaf (2018). Here, we take the concepts of greenspaces and green infrastructure to mean all natural vegetation and vegetative technologies that collectively provide society with a broad array of products and services that promote healthy living.

In general, research has demonstrated that contact with nature and green infrastructure has psychological benefits. For example, it can restore attention (Bodin and Hartig 2003; Hartig *et al.* 1991), lower blood pressure (Hartig *et al.* 2003), and reduce symptoms of attention deficit disorder in children (Faber-Taylor *et al.* 2001). Even passive viewing of natural spaces has been shown to reduce aggression associated with mental fatigue (Kuo 2001; Kuo and Sullivan 2001), reduce stress (Ulrich *et al.* 1991), and improve recovery times (Ulrich 1984).

Contact with nature and green infrastructure also has direct health benefits. For example, research has demonstrated that urban green space users have greater longevity (Takano *et al.* 2002; Tanaka *et al.* 1996), improved self-reported health (de Vries *et al.* 2003), and increased physical activity levels (Kaczynski and Henderson 2007), the latter of which should invariably improve both physical and psychological health. Further health benefits are brought about by the moderation of adverse environmental conditions such as air pollution, high temperatures, and noise (Gidlöf-Gunnarsson and Öhrström 2007; Whitford *et al.* 2001). Finally, natural spaces and open areas may promote social cohesion (Newton 2007) and enhance sense of

[1] See https://www.arborday.org/programs/treecampususa/campuses.cfm for a list of the current Tree Campus USA Schools (last updated June 2018).

community in residential areas (Kim and Kaplan 2004). These studies collectively suggest that green infrastructure has considerable potential for improving the health of urban residents (though see Tzoulas *et al.* 2007 for a discussion of potential limitations to this statement).

Specific to college and university campus landscapes, research has largely focused on how green spaces impact student health and student life experiences. Though research is more limited and sample sizes smaller, studies by McFarland *et al.* (2008), Seitz *et al.* (2014), and Windhorst and William (2015) suggest that both direct exposure to and passive viewing of natural spaces has a number of psychological and direct health benefits on students. For example, McFarland *et al.* (2008, 2010) examined the relationship between undergraduate and graduate student uses of campus greenspaces and their perceptions of quality of life at the University of Texas. Undergraduates that were considered frequent users of greenspaces experienced a higher self-reported quality of life compared to those that spent less time in the university arboretum (McFarland *et al.* 2008). Though this trend was not apparent in graduate students at the same university (McFarland *et al.* 2010), the discrepancy may be explained by greater use and awareness of university greenspaces among undergraduates, along with relatively low self-reported levels of stress by graduate students regardless of greenspace exposure. Seitz *et al.* (2014) conducted a study in which students at a public university in the southeastern United States were asked to photograph areas of campus they visit with the purpose of alleviating stress. Common themes among student photographs and subsequent discussion included alleviating stress through disengagement from academic pressures, mediation, prayer, and socialization in areas that predominantly featured mature trees, streams, and wildlife. A similar study by Windhorst and Williams (2015) included twelve university student participants who attributed feelings of solitude, relaxation, and self-reflection as the primary motives to spend time in natural places. Such places were identified as being beneficial to their mental health.

Trees and their Ecological Services

Whereas much of the literature described previously aggregates trees with other types of natural spaces, research on the ecological benefits (and costs) of urban trees and urban forests – distinct from other green infrastructure – is commonplace. Trees in urban and peri-urban environments provide a number of ecosystem services to urban residents (Bolund and Hunhammar 1999; Livesley *et al.* 2016). To date, urban trees have been found to remove nutrient pollutants and some heavy metals from stormwater (Denman *et al.* 2016), intercept rain and reduce stormwater runoff (Berland *et al.* 2017; Xiao and McPherson 2016), improve air quality by way of reducing airborne pollutant levels (Jim and Chen 2008; Nowak *et al.* 2006), provide habitat for birds and other animals (Fernández-Juricic and Jokimaki 2001; Gehrt and Chelsvig 2004), and sequester and store carbon (Brack 2002; Nowak and Crane 2002; Nowak *et al.* 2013; Schmitt-Harsh *et al.* 2013). The magnitude of these ecological "services" depends on past land use, scale, and species, and it should be noted that equally noteworthy areas of research aim to understand and quantify the potential "disservices" of urban trees. For example, while urban forests often provide pollution reduction benefits, certain urban tree species can emit biogenic volatile compounds (BVOCs) that act as a precursor to smog or ozone formation (Calfapietra *et al.* 2013). Some urban trees also release high volumes of allergenic pollen, which can have an adverse impact on the health and well-being of people (Cariñanos *et al.* 2016). Finally, while some research demonstrates urban trees having a positive effect on stormwater nutrient loading (Denman *et al.* 2016), others have demonstrated that vegetation near streets contributes substantially to stormwater nutrient pollution and downstream eutrophication of surface waters (Janke *et al.* 2017). While trees and associated vegetation promote nutrient uptake, deposition of the nutrient-rich leaf litter onto streets that are connected to storm drains can serve as major source of nitrogen (N) and phosphorus (P) (Janke *et al.* 2017).

Specific to college and university landscapes, we found few peer-reviewed articles documenting the ecological services or disservices of campus trees; however, there are many technical reports that represent collaborative work done by students, staff, and faculty. Examples include campus tree reports by Auburn University (2011), Southern Methodist University (2013), University of Arizona (2012), University of California San Diego (2009), and University of Pennsylvania (2015). Each of these reports utilize, at least in part, the Forest Service's i-Tree program to quantify the ecosystem services for all campus trees or a sample of trees on campus. The i-Tree tools are free and provide a number of opportunities to engage students in the process of data collection, processing, and modeling.

Study Methods

Study Design and Participant Recruitment

Survey participants were recruited using three strategies. These alternative strategies collectively aimed to solicit feedback from as wide of a network of colleges and universities around the United States and Canada as possible, including institutions with established tree management plans and institutions that lack a *recognized* tree management program (as determined via participation in the Arbor Day Foundation's Tree Campus USA certification program).

Strategy 1: Recruitment of Participation from Institutions Recognized as Tree Campus USA

The authors began with a list of institutions that are known to have tree care management plans given their participation in the Tree Campus USA program. The Arbor Day Foundation maintains a contact list for all schools currently certified. These schools were contacted via email in the fall of 2017 by the Arbor Day Foundation to solicit their feedback on the survey. The email was sent to **314 private and public colleges and universities**, but did not extend to any schools with active applications for consideration of Tree Campus USA designation.

Strategy 2: Recruitment of Participation from Stratified Random Sample of Institutions

To increase our sample size and be more inclusive of schools that do not have active associations with the Tree Campus USA program, we identified additional institutions to distribute our survey to using the 2015 Carnegie Classification of Institutions of Higher Education[2] system (Carnegie n.d.). We employed a stratified random sampling approach to identify schools with varied "control" (private; public) and "level" (2-year; 4-year and above). Six strata were identified including: private for-profit, private-not-for-profit, and public, for both 2-year and 4-year institutions. The resulting number of schools in each strata was large (from a minimum of 83 to a maximum of 1,644), and therefore 5-10 percent of each strata was selected for sampling using a random number generated approach.

There is not currently a comprehensive database that lists the contact information of facilities staff members, arborists, or other university members who are active in campus tree management efforts. As a result, contact information was obtained through a simple, but time intensive, google search process. The 5-10 percent sampling rate was identified as an appropriate goal given the time and effort required to search out contact information for each potential participant. University websites were searched to identify the person(s) responsible for campus tree care (e.g., grounds manager, grounds supervisor, arborist). Lacking this information, an individual with senior administrative responsibilities (e.g., facilities director, physical plant director, associate vice president for facilities management) was sent the survey. Using the stratified sampling approach, an additional **317 private and public colleges and universities** were selected for participation in the tree survey.

Taken collectively, a total of 631 colleges and universities were contacted to participate in the tree survey in September 2017. Of the colleges and universities sampled, 314 were Tree Campus USA schools and the remaining 317 were not. For roughly half of the schools, more than one person was contacted to participate

[2] The Carnegie Classification includes all Title IV eligible, degree-granting colleges and universities in the United States that are represented in the National Center for Education Statistics IPEDS system. The Carnegie Classification from 2015, which represents the most recent data for 4,665 colleges and universities, was used in this research (Carnegie n.d.).

in the survey, generally including a facilities director, a campus arborist (where applicable), and a grounds supervisor (or like position). Though the sample was drawn randomly, it covered a broad geographic area, with schools in all but one state (Hawaii) receiving the survey.

Participants were recruited via email from late September to early December 2017. Survey delivery used elements of Dillman's Tailored Design Method (Dillman 2000). The initial email explained the study purpose, the importance of completing the survey, and a link to the survey. A reminder email was sent approximately 10 days after sending the survey, and a final notice was sent to nonrespondents and those that partially completed the survey one month after the initial mailing. All respondents received a thank you note for their participation.

Strategy 3: Recruitment of Participation from APPA member institutions

The response rate from the first recruitment approach was low and many of the returned surveys were only partially complete. Simultaneous to closing the survey, the authors were seeking alternative ways to solicit participation from facilities departments at colleges and universities. In February 2018, the authors submitted an application to the Center for Facilities Research (CFaR). CFaR was established in 2002 by APPA, Leadership in Educational Facilities, to organize and consolidate research in educational facilities management. Our application explained the campus tree survey project and requested assistance in disseminating the survey to APPA members. Upon acceptance of the proposal, the survey was disseminated in March 2018 to the 18,000+ APPA members via an email blast and via publication in the biweekly enewsletter called *Inside APPA*. Similar to Strategies 1 and 2, elements of Dillman's Tailored Design Method were employed. Because the database of 18,000+ individuals includes multiple individuals per institution (including non-facilities members), we received a number of "duplicate" responses per institution. Since we're primarily interested in institutional-level tree care and management, we eliminated duplicate responses from the same institution (see Study Findings/Survey Completion section).

Survey Instrument

Prior to administering the survey instrument to institutions of higher education, the survey was pilot-tested by a handful of peer reviewers (n=5) known to be affiliated with campus tree management, including individuals in sustainability, facilities, and grounds manager positions. These individuals were asked to review the survey and provide their feedback on survey layout, organization, question clarity, question redundancy, and more. Our request for feedback was sent via email and the survey was revised and finalized following the review process.

The Qualtrics online survey platform was used to collect survey responses. The survey contained institutional-level and tree program-level questions. Survey questions were presented in a variety of formats and organized into seven sections. The *background* section asked respondents to answer basic multiple choice questions about their position, their primary role within the position, and the control (private vs. public) of the institution. The *tree cover* section asked respondents a number of multiple-choice and fill-in-the-blank questions aimed at understanding the percentage, area, and number of trees on campus. Respondents were also asked questions about tree planting and tree canopy goals, and how such goals were developed. The *tree surveys* section asked respondents about the collection and maintenance of tree inventory data on campus.

The *tree program management* section included questions about decision-making authority as it relates to tree planting and removal, and how such decisions are made. It asked respondents to reflect on why trees are planted and what happens to trees when removed, and requested information on strategic plans created to

manage trees. The *resources and budget* section asked respondents to provide a range of information about the resources available for tree planting and maintenance efforts, including monies for full-time staff. A question about the professional background and experience of individuals responsible for tree management were also included in this section. The *SWOT analysis* section asked respondents to identify the four most significant strengths, weaknesses, opportunities, and threats that they associate with their institution's tree program. This was included following the successful use of the technique by Britt and Johnston (2008) and Stobbart and Johnston (2012). The final *edible trees* section asked respondents to answer a small number of questions about the presence of edible fruit and nut trees on campus. These questions were included with the intent of developing a follow-up study focused on campus orchards and edible forests, and are not analyzed here.

Over half of the survey questions were formatted in a simple multiple choice format. The remaining questions were fill-in-the-blank, drag and drop, and questions that assessed the degree to which various factors were important in tree planting and maintenance decisions. Survey questions were modeled after a recent survey by Hauer and Peterson (2016) that was administered to *municipalities* around the United States. Other surveys developed and administered in New Zealand (Stobbart and Johnston 2012), Germany (Gerhardt 2010), and Great Britain (Johnston and Rushton 1998) were also reviewed and were useful to the development and refinement of questions.

Analysis

After closing the survey, data were exported from Qualtrics, screened for errors and omissions, organized, and analyzed using Microsoft Excel and SPSS Statistics 22. Descriptive statistics were then generated for the survey data. Results are presented for a select number of closed format and open-ended questions. In all cases, the percentage of the total number of responses is presented. For questions that some respondents left blank, the authors divided by the total number of actual responses for that particular question. For some of the closed format questions, percentage totals exceed 100% because respondents were not forced to choose only one option. Responses to open-ended questions are used primarily for explanatory purposes, to qualify findings shown through analysis of closed format questions.

Where relevant, institutions were categorized and compared as a function of "control" (public, private) and "level" (2-yr, 4-yr). Information about the institutional size, which is defined here as the number of full-time equivalent students, was also sought to typologize institutions because institutional size often relates to institutional structure, complexity, culture, and finances. The *background* section of the survey was kept purposefully brief given the length of the whole survey, so we solicited information about control, level, and institutional size from external datasets managed by the Carnegie Classification of Institutions of Higher Education system (Carnegie n.d.). In the end, we utilized control and level to examine differences (and similarities) in responses; institutional size categories were numerous and not defined equally across institutions so we report institutional size (see Table 1) but do not use it in further analyses.

Study Findings

Survey Completion

A common casualty of online multi-part surveys is the attrition of survey respondents in completing the survey. Our survey software accepted incomplete responses from individuals who answered at least one question. Over 900 respondents clicked on the link to respond to the survey, of those 545 individuals made it far enough into the questionnaire to answer key questions about their campus tree care activities. Some of our respondents were from k-12 schools, independent research centers, and the commercial private sector, likely because they were on the APPA email listserv. Such respondents were removed from analysis given our focus on institutions of higher education.

We also removed, or more appropriately pared back, duplicate responses. As a result of our sampling approach, upwards of 100 institutions were represented more than once (with 2 to a maximum of 5 individuals responding per institution). Since we're primarily interested in institutional-level tree care and management, we eliminated duplicate responses from the same institution as follows: First, where multiple individuals from the same institution responded to the survey, a complete survey response (containing no missing answers to questions) was kept over an incomplete response. Second, where multiple responses from the same institution were *complete*, the set of responses from the person more directly responsible for campus tree care was kept over the person(s) with more senior administrative responsibilities. Third, where multiple responses were recorded from the same *individual* (given multiple methods to target feedback), we selected the most complete and the most recent response.

The above rules in-use narrowed **the participant size to 378 institutions** (response rate indeterminate given sampling method). This does not include any duplicated responses. Non-item response errors were common, in part a function of attrition, but also because of skip logic embedded into the questionnaire. Thus, some of the results described below include fewer than 378 respondents. For questions that some respondents left blank, the authors divided by the total number of actual responses for that particular question. For some of the closed format questions, percentage totals exceed 100% because respondents could select more than one option.

Participating Institutions

Geographic Location of Respondents

Institutions in each of the 50 states and Washington, D.C., with the exclusion of Delaware, participated in the survey, with some states having just under 30 participating institutions. **Figure 1** shows the number of institutions that responded per state and their

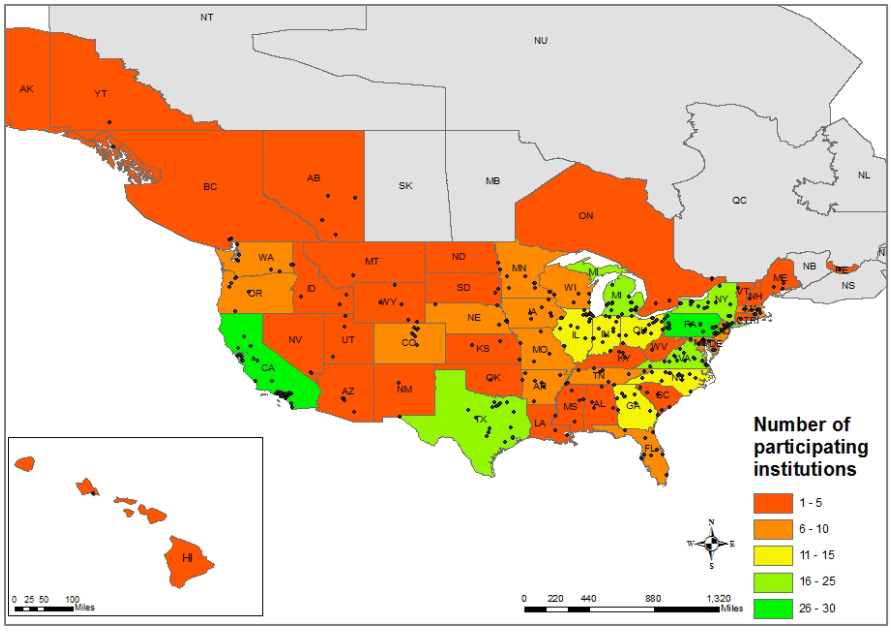

Figure 1. Number of participating institutions per state. (n=378)

approximate location, and **Appendix 1** provides the name and location of each responding institution. Twelve of the responding institutions were from Canada, representing four Provinces (Alberta, British Columbia, Ontario, and Prince Edward Island) and one territory (Yukon).

Institutional Characteristics of Respondents

The majority of respondents were from 4-year public institutions (n=200) and 4-year private not-for-profit institutions (hereby referred to simply as private institutions) (n=142), with a small number of respondents from 2-year public institutions (n=36) (**Table 1**). The institutional size (student population) of participating institutions varied widely, from less than 1,000 full-time equivalent students to greater than 40,000 students (Carnegie n.d.) (**Table 1**). A number of colleges with active Tree Campus USA certification participated (n=138, 36.5%), though the majority of respondents do not currently participate in the program (n=240, 63.5%).

Table 1. Participating institutions by control, level, and enrollment size, determined by the number of full-time equivalent students enrolled.

		Tree Campus USA certified	
Classification[1]	Respondents (n)	Yes	No
Total, all institutions	**378**	**138**	**240**
Two-year public	**36**	**7**	**29**
Small (500 – 1,999 students)	3	0	3
Medium (2,000 – 4,999 students)	13	2	11
Large (5,000 – 9,999 students)	14	4	10
Very large (≥ 10,000 students)	6	1	5
Four-year public	**200**	**88**	**113**
Very small ((≤ 1,000 students)	1	0	1
Small (1,000 – 2,999 students)	13	4	9
Medium (3,000 – 9,999 students)	63	20	43
Large (≥ 10,000 students)	122	64	58
Exclusively graduate/professional	1	0	1
Four-year private	**142**	**43**	**99**
Very small (≤ 1,000 students)	6	1	5
Small (1,000 – 2,999 students)	78	22	56
Medium (3,000 – 9,999 students)	40	14	26
Large (≥ 10,000 students)	17	6	11
Exclusively graduate/professional	1	0	1

[1] Classification categories are set by the Carnegie Classification of Institutions of Higher Education. Note that the classifications are time-specific snapshots of institutional attributes and behavior. The categorization used here is based on 2013-14 data (Carnegie n.d.)

Campus Tree Cover and Goals

Number of Campus Trees

As discussed in the **Introduction,** the "campus forest" includes trees in open spaces, in landscaped beds, in "wild" areas on campus, gardens, along streams, in wooded "pocket" parks, and so on. Given the diversity of locations and landscape characteristics, there are several ways one could quantify the campus tree resource. One simple enumeration involves reporting the total number or abundance of trees. Another involves calculating the density of trees, either in terms of trees per unit area, basal area, or per capita. Our

survey asked respondents to report both the total number of trees on campus *and* the areal extent of campus (in hectares or acres) from which we could get an estimation of tree density.

The institutions that participated in this survey study were diverse in their estimated tree abundance and areal extent of campus. To the question "What is the total number of trees that are currently planted on your campus?", we received responses that ranged from 10+ trees to 50,000 trees. We binned responses into 10 groups based on natural breaks in the data, and the resulting histogram is shown in **Figure 2**. The majority of respondents indicated having 1,001 to 2,500 trees (n=78) and 2,501 to 5,000 trees (n=70) (**Figure 2**). Of those that responded to this question (n=305), the majority (72.2%) indicated that the tree count was an "estimate" while 27.8% indicated it was an "accurate" record. A presumed way to have an accurate record of tree counts is via an inventory, which respondents were later asked about (Every school but one that indicated the tree count was "accurate" later identified having a campus tree inventory). The survey respondents that did not provide a tree count estimate (n=73) cited that they were "uncertain".

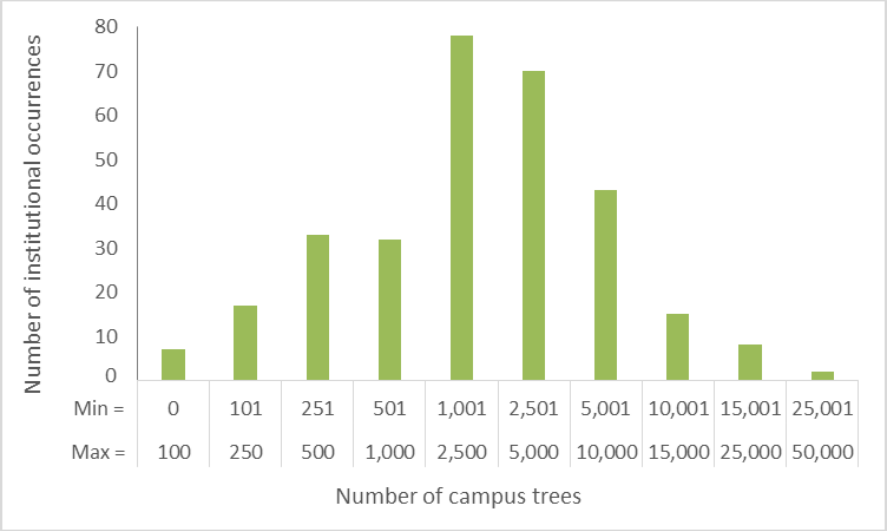

Figure 2. What is the total number of trees that are currently planted on your campus? (n=305)

Though some respondents cited an "accurate" record of tree abundance, we recommend caution in the use and interpretation of the data shown in Figure 2. Without a complete tree inventory, including an up-to-date record of recent tree planting activities, it is difficult to accurately ascertain tree abundance. Even in cases where tree canopy studies have been conducted, tree canopy is not a replacement for tree abundance. Further, we have no way of knowing with certainty whether responding institutions considered *all* campus trees in their estimate (on- and off-campus), whether they report tree counts for "wild" areas, and so on. Rather, these estimates are provided here as a first attempt to quantify tree campus resources across a range of institutions.

Tree Density

The survey asked respondents to report on the total area of their campus. A number of respondents did not respond to this question and of those that did, many responses were indicated to be "estimates" rather than "accurate" accounts. So we sought to supplement and confirm our survey data responses with external databases. For consistency, we utilized the U.S. News Database and searched for each responding institution using the U.S. News Best Colleges Ranking 2019. For schools lacking information on this webpage (e.g., most two-year public institutions and institutions located in Canada), we went directly to their homepage to search for the information. By area, responding institutions ranged from 10 acres to 17,000 acres. The density of trees reported ranged from less than 1 tree per campus acre to 291 trees per acre. The upper calculation was deemed to be outlier given that the next highest tree density calculated for institutions was 1.7 times smaller (167 trees/acre). Overall, this component of the data has little prescriptive or analytical

value given the number of sources and estimations employed in both campus acreage area estimations and tree abundance estimations.

Tree Planting and Canopy Goals

Currently 36% of responding institutions indicated they either have a tree *planting* goal (20.4%) or are developing one (15.6%). The frequency was higher for four-year public institutions than for other institutional groups, with 42% of respondents from four-year public institutions identifying having or being in the process of developing a tree planting goal, as compared to 31% from four-year private institutions and 22.2% from two-year public institutions (**Figure 3A**). Respondents were asked to describe their tree planting goal and responses varied considerably. For example, some institutions identified their goal based on a certain number of trees planted each year (e.g., 15 trees per year for 20 years); others provided a final tree planting count to be achieved by a given date (e.g., 100 trees by 2022); and others described a tree planting strategy that was determined by replacement (e.g., one for one replacement).

We also asked respondents a similar set of questions oriented around tree canopy goals. Urban tree canopy generally refers to the layer of tree leaves, branches, and stems that provide tree coverage of the ground when viewed from above (https://www.nrs.fs.fed.us/urban/utc/). It is most commonly determined from analysis of aerial photographic surveys, satellite imagery, fine-resolution images captured by drones, or some combination of these sources. Tree canopy assessments can help decision-makers better understand the current amount and spatial arrangement of tree resources, and the amount that could exist at multiple scales. Currently 20.9% of responding institutions indicated they either have a tree canopy goal (8.7%) or are developing one (12.2%). Similar to tree planting goals, the frequency for tree canopy goals was higher for four-year public institutions than for other institutional groups, with 24.5% of respondents from four-year public institutions identifying having or being in the process of developing a tree canopy goal, as compared to 17.6% from four-year private institutions and 13.9% from two-year public institutions (**Figure 3B**).

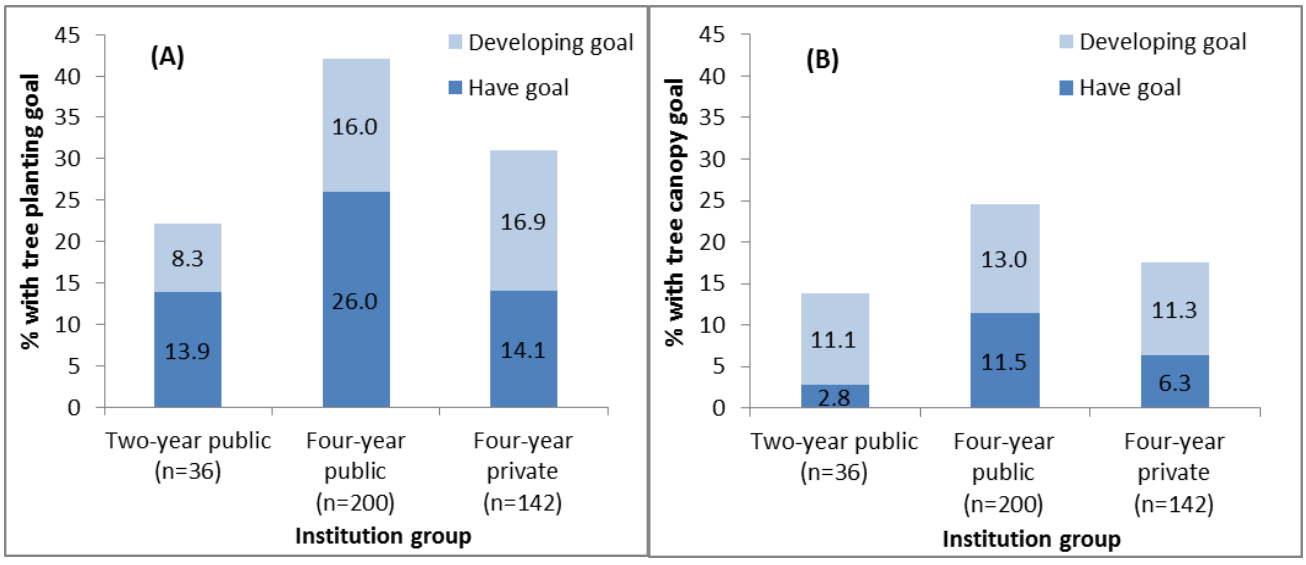

Figure 3. (A) Does your institution currently have a tree *planting* goal? (n=378) **(B)** Does your institution currently have a tree *canopy* goal? (n=378)

Tree Inventory Efforts

The availability of urban forest inventory systems in the past few decades, including Plan-It Geo's Tree Plotter app, the Urban Forest Metrix, the Tree Tracker, and the U.S. Forest Service's i-Tree tools, provides practitioners and researchers opportunities to better manage tree populations and estimate ecosystem services in a more timely and efficient manner. While the use of tree inventories dates back to at least the 1800's, since that time the methodology has transitioned from a predominantly paper-based inventory system to computer-based database systems, Geographical Information Systems (GIS), and spatial locating systems such as Global Positioning Systems (GPS) (Hauer and Peterson 2017; Miller *et al.* 2015). In some cases, tree inventories are repeated on a scheduled basis ("re-inventoried"), and this kind of systematic data collection can help practitioners, researchers, and urban forest decision-makers better understand tree population characteristics (e.g., diversity, age, size class distributions), tree conflicts, and pest issues over time.

Two-thirds of the responding institutions (n=252, 67%) indicated they have some level of a tree inventory. By institutional group, 71.5% of all four-year public universities indicated they have a tree inventory, 64.8% of all four-year private universities and half of the two-year public universities indicated they have a tree inventory (**Figure 4-A**). A little over half of all respondents indicated their inventory was computerized; by institutional group, four-year public universities more commonly had computerized inventories than four-year private universities and two-year public universities (**Figure 4-B**). Respondents were asked to describe the software they used to collect and track inventory data and responses included Microsoft Excel, Microsoft Access, ArcGIS, ArborPro, ArborScope (Bartlett Tree), Tree Plotter (Plan-It Geo), TreeWorks (Community Forestry Consultants Inc.), and TreeKeeper (Davey Tree).

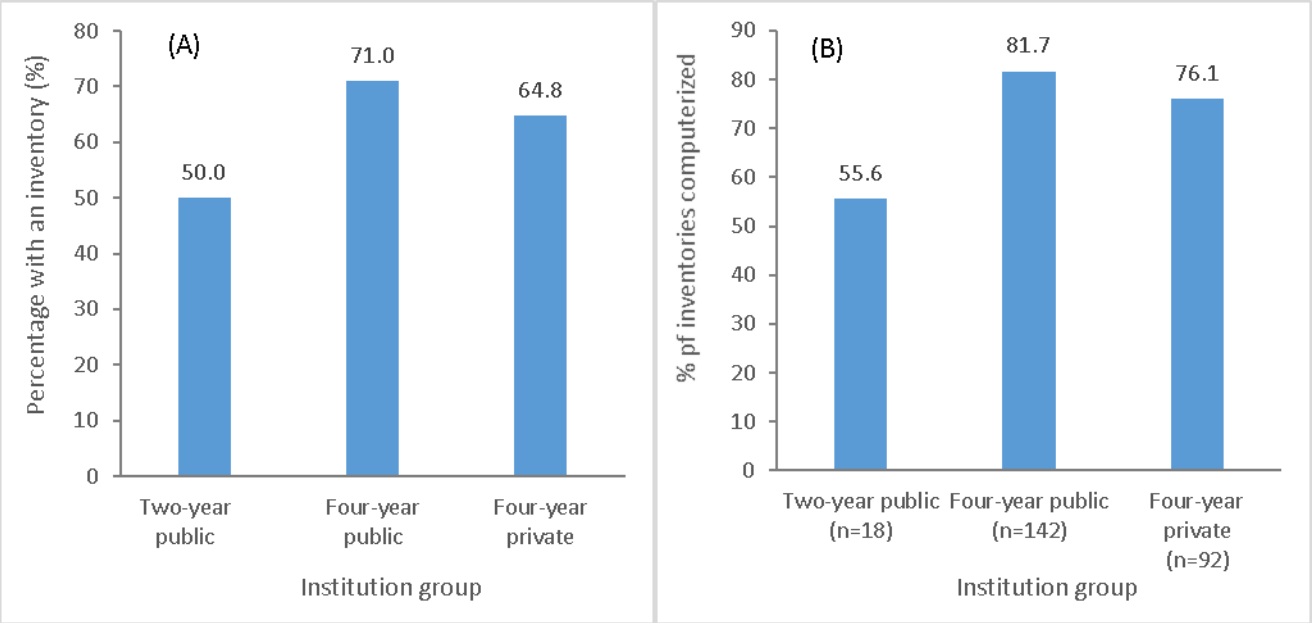

Figure 4. (A) Does your institution have a tree inventory? (n=378). **(B)** For those that *do* have a tree inventory, is your inventory computerized? (n=252).

Tree inventories can be completed by many people including facilities staff, hired consultants, volunteers, interns, students, faculty, arborists, municipal employees, or state employees. An institution can use one, two, or many people to complete an inventory. When asked "Who contributed to your tree inventory?", 78% of respondents indicated facilities staff were used to collect tree data; 37.7% indicated contractors were used; students were used by 36.1%; faculty by 28.2% (**Figure 5**). Municipal and state staff were written in as "other" by 3.2% of respondents, and tree "specialists" such as arborists, landscape architects, and arboretum staff were written in by 6.3% of respondents.

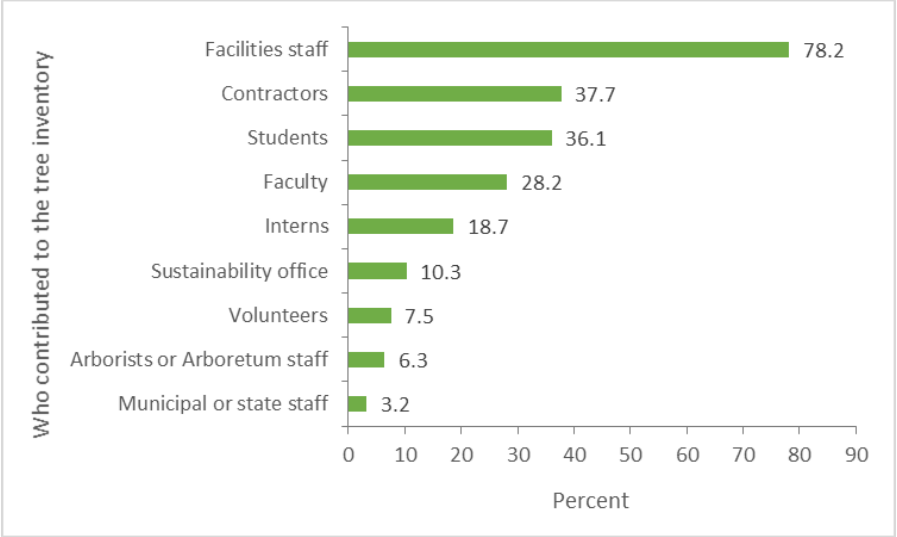

Figure 5. Who contributed to your tree inventory? (n=252)

Tree Inventory Uses

An inventory of the campus forest establishes a baseline for setting management objectives by determining what you have and where you have it (Alvey 2006). But before a tree inventory is conducted, there is ideally a series of questions that are discussed to determine what the aim of the inventory is and how the information collected will be used. For example, one could ask: Do we want to collect tree height measurements, and if so, how will that information be used? Do we have the capability (technical expertise and time) to collect information about tree condition and/or tree risks? Depending on financial resources, information may be gathered for all trees on campus grounds, a sample of trees, or only a specific component of the campus forest, such as in open spaces or in campus woodlots. Personnel demands, resources, and expected time to completion need to be taken into consideration when determining *how* and *where* to inventory campus trees. While inventorying a sample of campus trees may be more cost-effective and require fewer personnel for a shorter period of time (as compared to inventorying the entire campus), the data collected (DBH, height, risk assessment, condition) can also have an impact on both time and cost effectiveness. Within municipal areas, Nowak *et al.* (2008) conducted research on this subject and noted that the number and size of sample plots are the major factors that urban forest managers need to consider when evaluating the protocols to follow and their effects on the overall costs. Further, time for data analysis and updating must also be taken into account (Jaenson *et al.* 1992). A number of universities employ students to help with data collection, though there may be

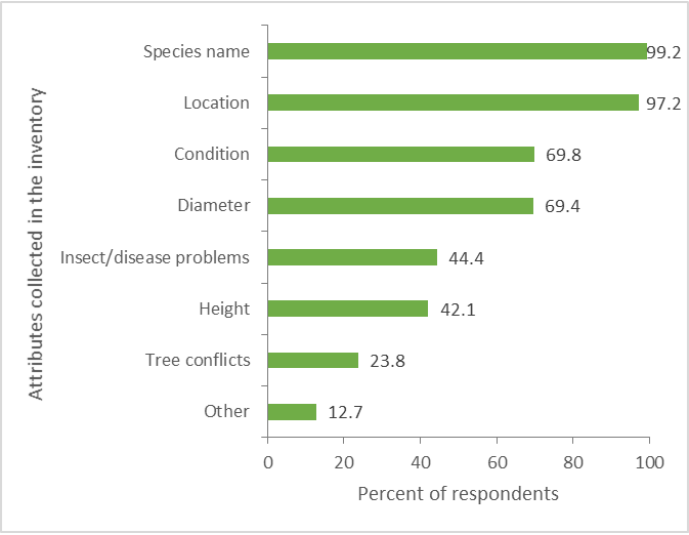

Figure 6. Which of the following is identified in your inventory? (n=252)

tradeoffs in data precision and accuracy unless the student(s) are adequately trained.

Among the 252 institutions that indicated the presence of a tree inventory, most collected information about the tree population by identifying tree species (99.2%), tree location (97.2%), tree diameter (69.4%), and tree condition (69.8%) Other information collected included insect/disease problems (44.4%), tree height (42.1%), tree conflicts (23.8%), and "other" (12.7%) to which common responses included tree risks, the year planted, identification of memorial trees, and estimated tree value (**Figure 6**). Approximately 70% of the responding institutions with a tree inventory identify four to eight tree attributes in the inventory (though *which* attributes varied). The remaining 30% collected three or fewer attributes, most commonly including (but not always) tree species, location, and either condition or tree diameter.

Tree inventory data can be used to track tree performance, tree maintenance activities, and tree benefits, through modeling of ecosystem services. Respondents were asked to report on the activities that are impacted by tree inventory information, and identifying tree planting locations was the most commonly selected response (72%) (**Figure 7**). Tree selection (69%), tree removal (62%), and scheduling pruning or selecting trees for pruning (55%) were also common. Fewer than half (40%) used tree inventories to communicate tree benefits to institutional stakeholders or to the community at large (37%). Approximately 10% of respondents identified additional "other" activities that the inventory was used for, including the management of pests and diseases, modeling of tree value, and reporting of storm damage (**Figure 7**).

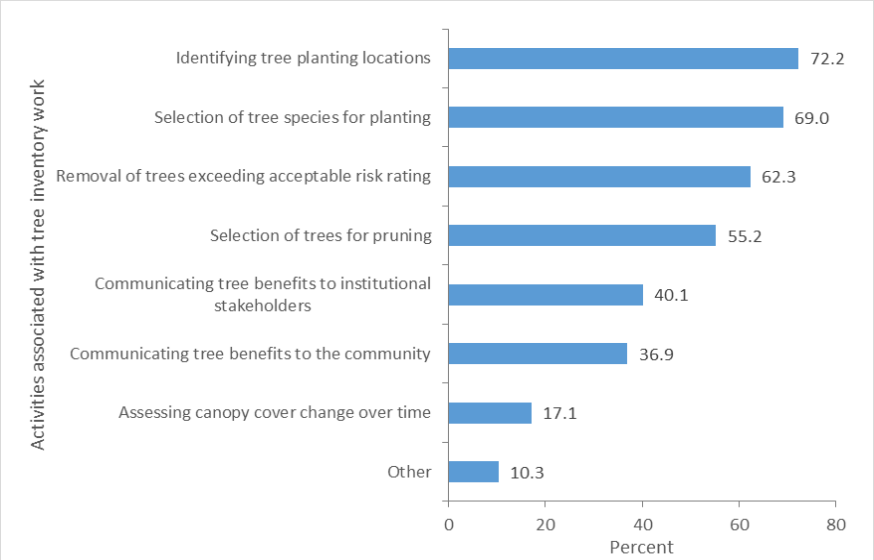

Figure 7. Is your tree inventory used to direct any of the following tree management activities? (n=252)

Tree Operations and Management

Major Activities

Campus tree operations includes a number of activities that may include, but are not limited to, planning, planting, inventorying, pruning, watering, fertilizing, controlling pests, storm cleanup, and removing trees. These activities can be performed ad hoc, or planned and systematically scheduled. Similarly, they can be performed by in-house university staff or contracted out. There's a number of ways one could ask questions to obtain information about the relative effort, time spent, or dollars expended to support each activity. We examined the relative importance of each tree care activity through the lens of expenditures. We asked respondents to identify the work activities that comprise the largest share of the total tree care budget.

In terms of the major expenditures associated with tree care and maintenance, three major work activities dominate: planting, pruning, and tree removal, including the removal and disposal of tree waste. Closely following is the cleanup of tree debris associated with storm damage (**Figure 8**). This corresponds to findings by Giedraitis and Kielbaso (1982) and Kielbaso *et al.* (1988), who examined major tree expenditures in municipalities around the U.S. One tree care activity that was unintentionally omitted in our survey was pest and disease management. Respondents were given the opportunity to write in "other" activities and 10 institutions (2.9%) described spraying for insect/disease problems and other pest management activities. It's likely that our survey results underestimate this tree maintenance activity given the rapid spread and impact of many pests (such as the emerald ash borer (EAB), gypsy moth, and Asian longhorned beetle) and diseases (such as oak wilt, pine wilt, and thousand cankers disease).

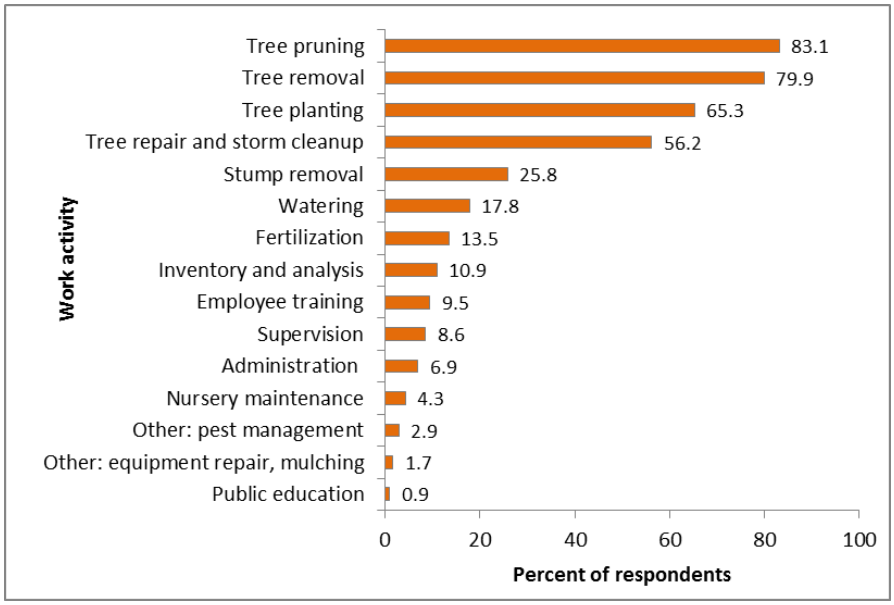

Figure 8. Which of the following activities comprise the largest share of the tree care budget? Please identify the 4 activities that comprise the largest share of the budget. (n=349)

For two of the most commonly identified tree activities that draw from the tree care budget – tree planting and tree removal – we asked a number of follow up questions (see next sections). We did not ask questions about tree pruning (primarily due to survey length and resultant potential of survey fatigue). Future survey efforts could focus attention to this topic.

Tree Planting

Tree planting comprises one of three top activities requiring tree care funds. Planting efforts may include tree ordering, purchasing, tree production in a nursery, planting site preparation, actual planting, mulching, staking, initial watering, and other activities to promote establishment. *Why* trees are planted was of interest to us, particularly as this survey arrives at a time when many universities are setting tree planting goals, be they diverse in how they are structured and achieved. Respondents were asked to indicate the relative degree to which various factors determine tree planting decisions on campus property. For example, are trees planted for aesthetic reasons, to reduce heating and cooling costs, to reduce atmospheric pollutants, to provide educational opportunities for students, or as a result of all four factors?

The most commonly cited reason for trees to be planted was aesthetics, with over two-thirds of institutions selecting aesthetics as "very important" and the remaining selecting it as "somewhat important" in determining whether trees are planted (**Figure 9**). Two other common reasons include improved health of students and personnel, and educational opportunities for students. Environmental services provided by trees, such as stormwater management, provision of climate regulating services (e.g., carbon sequestration,

shading/cooling), and reduction of atmospheric pollutants (e.g., volatile organic compounds, VOC) were commonly reported as "somewhat important". Less important reasons for tree planting included attainment of certifications and awards, the provision of habitat for animals, and the provision of food for human consumption (**Figure 9**).

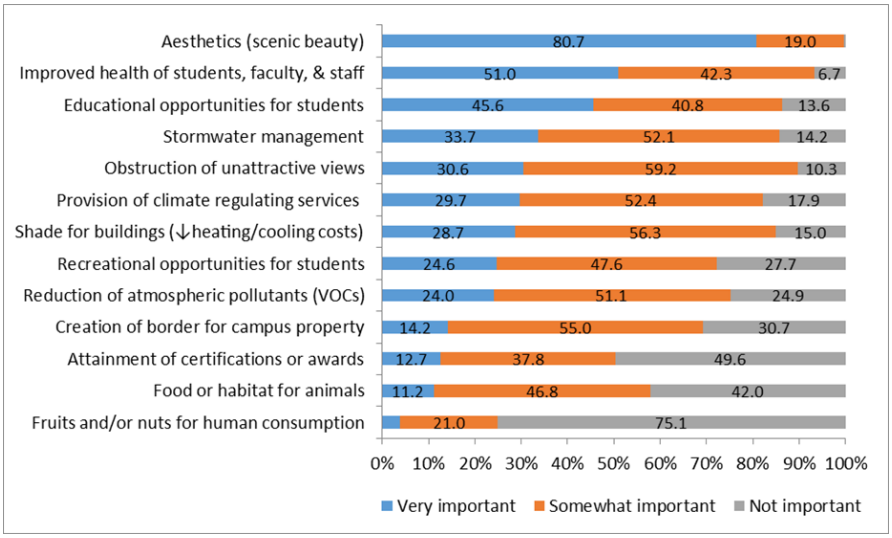

Figure 9. Which of the following are *formally* considered in the decision to plant trees on campus property? (n=365, though some categories had fewer responses (minimum n equaled 347).

Respondents were asked, in an open format, to describe the general process by which trees are selected for planting. We received a diverse set of responses, as expected, with some respondents explaining how or why certain tree species are selected for planting (see **Box 1** for example, representative comments), and others explaining the procedural actions employed to plant trees (see **Box 2** for example comments). A common theme among respondents falls in line with the arboriculture practice of "Right tree, Right place". Such decisions inevitably take into account environmental constraints (water, light, space, temperature, nutrient load), but may also factor the socio-cultural component (see Box 1).

Box 1. What is the general process by which trees are selected for planting? (n=345) Sample comments from six respondents explaining how or why certain tree species are selected for planting.

- "Determined based on site characteristics, species tolerances, value in terms of diversity with consideration for native ecology along with aesthetic value."
- "Acclimation to the area, availability, requirements of the space."
- "All trees grown (on) this campus must be from a reputable source, be in good health and of good structure. They must be sustainable in our climate, they should offer some aesthetic value and create educational opportunities. The trees should be suited for the physical location they are to be planted in, i.e. large trees should not be placed next (to) building foundations or utilities."
- "Based on location, risk, aesthetics, species and management. Goal is to increase tree species diversity along with planting the right species in the right place."
- "Diversity in tree species is the greatest driver in planting decisions."
- "First by design intent, then based on what species have been removed, proven species for campus and occasionally uniqueness for memorial or commemorative trees."

Box 2. What is the general process by which trees are selected for planting? (n=345) Sample comments from three respondents explaining the procedural aspects of tree planting.

- "For installations at new building sites or renovations, a landscape architect submits a landscape plan that is reviewed by Director of Landscape and Grounds and Campus Arborist. Recommended changes to the plan are then submitted through the contractor. In house plantings are proposed by Campus Arborist for approval by administration."
- "When trees are planted on campus the Landscaping Services Department chose the new planting locations and tree species to be planted. Those choices are then sent over to the Campus Planning Office to make sure they are not going to be in conflict with any future development plans. Once the locations are cleared by the Planning Office tree installation is scheduled during the next planting season. Other trees planted on campus are part of construction projects whose landscape planting plans have been reviewed by both the Landscaping Services Department and the Campus Planning Office."
- "30% Upper Administration, 30% Faculty, 40% Facilities Mgt. Facilities is tasked with planting trees that Admin. and Faculty would like to see planted and incorporates what is feasible or close to the desired tree, i.e., request was made for "fruit trees" but was left for Campus Arborist to decide which fruit trees would work best regarding soil, watering schedules, available sunlight, etc..."

Tree Removal Reasons and Disposal

Tree removals on campus are a regular part of tree maintenance and grounds management. The reasons for tree removal are often varied, just as are the disposal options. Trees may be removed due to an infrastructure conflict, insect or disease problem, storm damage, old age, or in preparation for a development project. Removal activities often include cutting, chipping, stump removal, clean-up, and brush and wood disposal; these activities may be performed in-house, contracted out, or both. Our survey specifically aimed to address *why* trees are typically removed on campus, and *where* solid wood and residue is disposed of following removal.

The most frequently identified reasons *why* trees were removed included tree death or decline (100%), disease/insect problems (84%), conflict with a development project (82%), and storm damage (79%) (**Figure 10**). These statistics represent simple counts. For example, how many of the respondents indicated that trees were removed because of damage to sidewalks? As shown in Figure 10, the answer is 90, or 24.8% of all respondents. We also asked respondents to indicate, by percentage, the relative impact of each "reason" on tree removal. For example, what percentage of all campus tree removals is because of damage to sidewalks? Here, the answer is less than 2%, on average (**Table 2**). In other words, if 100 trees were removed from campus,

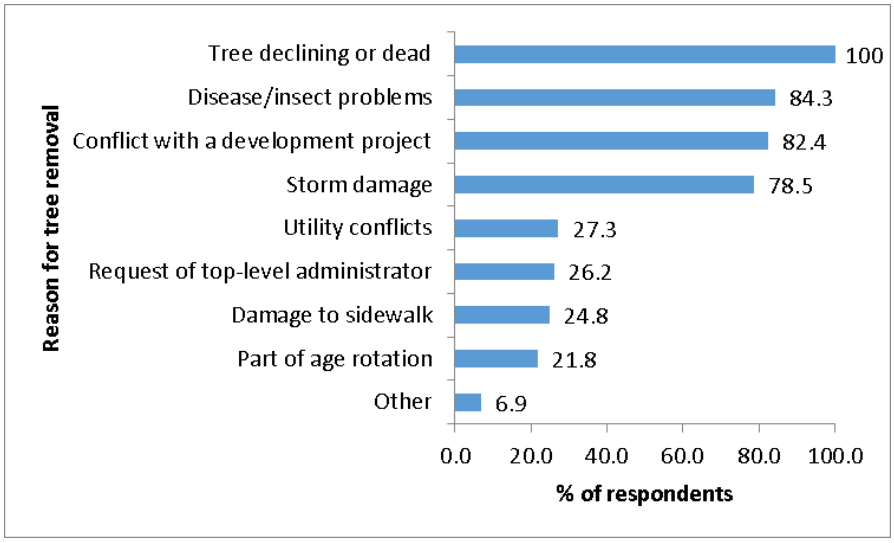

Figure 10. Which of the following reasons explain why trees are removed on campus? (n=363)

fewer than two of those trees were removed *because of* damage to sidewalks. For the most frequently identified reason for tree removal – tree death – some institutions indicated that 100% of removals are attributed to tree death, and therefore no trees are removed for other reasons. We received a wide range of responses for all tree removal categories, including tree death, where the median percentage for this tree removal category equaled 50% (**Table 2**). Similarly, some institutions indicated that conflict with a development project affects 90% of all tree removal cases, whereas some institutions did not cite this as a reason for tree removal. Interpreting this data is tricky given the wide variability, but we included it here to demonstrate some of the different rationales taken by colleges to remove trees.

Table 2. Which of the following reasons explain the current removal of trees on campus? Indicate, by percentage, the relative impact of each reason on tree removal. Mean, median, and range of responses are shown here. (n=363)

			Range	
Reason why removed	Mean (%)	Median (%)	Min (%)	Max (%)
Tree declining or dead	48.0	50	2	100
Conflict with a development	17.4	10	0	90
Disease/insect problem	14.0	10	0	80
Storm damage	9.6	8	0	50
Utility conflicts	4.5	2	0	33
Request of top-level administrator	1.9	0	0	30
Damage to sidewalk	1.5	0	0	20
Part of age rotation	2.1	0	0	40
Other	0.9	0	0	50

[1] Classification categories are set by the Carnegie Classification of Institutions of Higher Education. Note that the classifications are time-specific snapshots of institutional attributes and behavior. The categorization used here is based on 2013-14 data (Carnegie n.d.)

Respondents were asked, in an open format, to describe the general process by which trees are removed. We received a diverse set of responses, as expected, with some respondents focusing on the procedural actions taken to remove a tree, and others providing comments about why trees are removed (e.g., invasiveness, health, safety risk, and so on). Example comments on the procedural side of tree removal are shown in **Box 3.**

Box 3. What is the general process by which trees are removed? (n=355) Sample representative comments from six respondents focused on the procedural actions taken to remove trees are provided here.

- "Assessment and recommendation by a certified arborist, review/approval by provost, review/approval by stakeholder, removal by contractor."
- "Hazard trees are identified and reported to management who request approval from the President of the University to remove the tree."
- "Grounds supervisor inspection identifies damaged or dangerous trees. Removal contracted as soon as budget funds are available. Replacement tree planned in accordance with campus tree plan."
- "Grounds staff identifies the trees and works with an outside company for removal. They are supposed to inform the tree committee before anything is removed. Once removed, grounds informs the sustainability coordinator so it can be recorded in the tree inventory and for Tree Campus USA."
- "A tree is determined to be damaged, dying, diseased, or in the way of new construction and Campus Facilities. An Arborist is contacted to safely remove the tree."
- "All trees are resurveyed on a 1-2 year cycle by our campus arborist. Trees with evident disease or damage are surveyed as noted and a structural assessment which may include a Tree Radar - adapted ground-penetrating radar - is completed. Trees larger than 20" diameter in the historic core (of) campus receive an independent arborist evaluation."

After removal, trees may be disposed of in many ways, and more than one approach may be utilized. Over three-fourths of all respondents create mulch from campus trees (77.8%) (**Figure 11**). We did not inquire as to whether the mulch is created in-house or from a contractor. Other common disposal methods included production of firewood (40.5%) and disposal in a landfill (24.7%). A surprising 22.7% of respondents indicated processing trees into lumber for re-use either on- or off-campus.

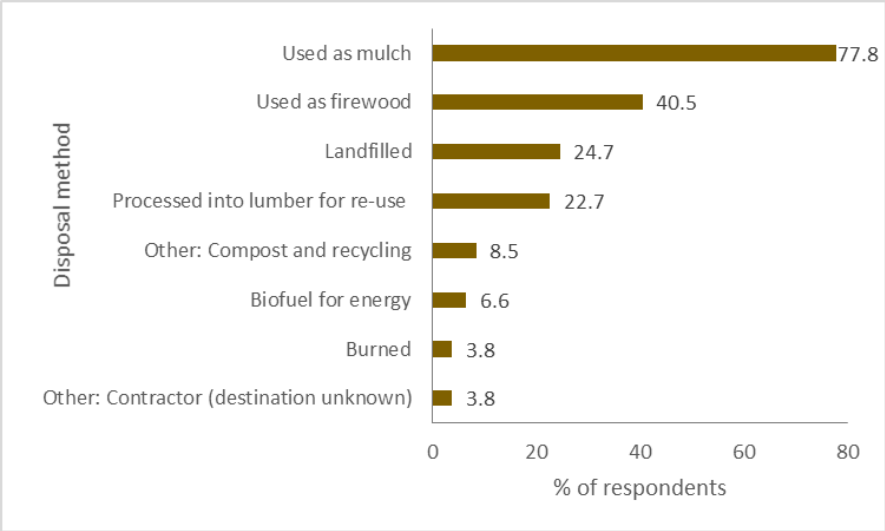

Figure 11. When a tree is removed, which of the following are typical ways that solid wood/residue is disposed of? (n=365)

Personnel and Budgets

Staff and Decision-Making Authority

The planting, care, and removal of trees on college campuses require a commitment of personnel and budget dollars from the college. We asked respondents a number of questions about staff training, decision-making authority, and adequacy of the current budget to support tree activities. How many management steps exist between staff conducting tree care and the highest level of decision-making is important (Hauer and Peterson 2017). And understanding the number of staff associated with tree care activities, including their training and credentials, can provide insight into the in-house capabilities of university staff to care for trees.

Regarding personnel involved in tree care and maintenance (including office administration), the average number of employees working with trees on a full-time basis is five. This does not include contractors who are engaged in operational and manual aspects of practical tree care (e.g., watering, fertilizing, and the like). Given the variability in responses to this question, reporting only the average is insufficient. **Figure 11** demonstrates the minimum, median, maximum, and quartile ranges of responses to the question of FTE staff involved in tree care activities. The median response for each institutional category did not differ much, ranging from 2.5 FTE for two-year public institutions to 4 FTE for four-year public institutions. What *did* vary between institutional groups was the maximum number of staff involved in tree care. One four-year public institution reported having 70 employees (full-time equivalent) involved in tree care (**Figure 11**). The maximum number of FTE staff for four-year private institutions was 40, and for two-year public institutions it was 15. For each institutional group, some respondents indicated there were no full-time employees to care for and maintain campus trees.

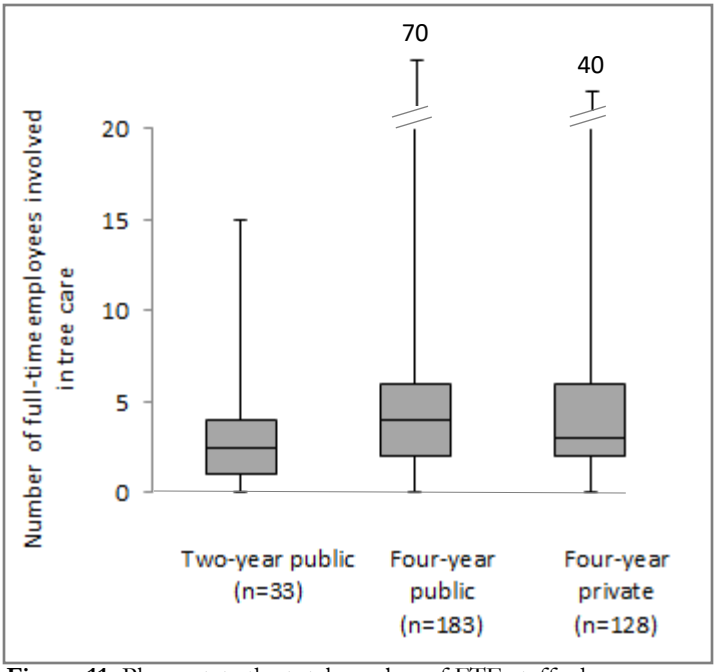

Figure 11. Please state the total number of FTE staff who are employed in the institution's care of trees. (n=344). Each "box" shows the median, 1st quartile, and 3rd quartile. Whiskers represent the minimum and maximum.

The number of decision-making steps for campus tree management varied slightly by institutional category. Over three-quarters of the respondents (76.7%) indicated having three (42.7%) or two (34.0%) levels of decision-making between the staff members who conduct tree work and the highest level of management. The remainder indicated having four levels (11.5%), one level (9.4%), and five or more levels (2.4%). When examined by institutional group, the same order was found though with small differences in percentage weight (see **Figure 12).** For example, a higher percentage of all two-year public institutions (55.6%) indicated having three decision-making steps, as compared to 46.8% of all four-year private institutions and 37.6% of all four-year public institutions. Less than 1% of all four-year private institutions and *no* two-year public institutions indicated having five or more decision-making steps (**Figure 12**).

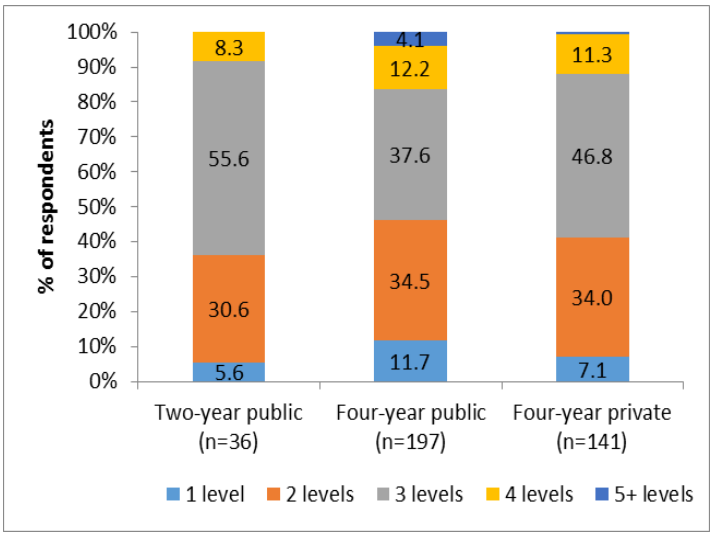

Figure 12. How many levels of decision-making typically happen between the top person in the institution who directs decisions about trees and the person who performs tree care activities? (n=374)

The training and credentials held by staff who are responsible for tree activities and/or the management of trees was ascertained. In-house training and/or on-the-job training (81.2%) and attendance at tree care/management workshops (69.5%) were common to all respondents (**Figure 13**). Training from credential systems by the International Society of Arboriculture (ISA), the Society of American Foresters (SAF), or a state-specific license were pursued by some institutions. The most commonly pursued certification among responding institutions was the ISA Certified Arborist program (44.5%). Advanced ISA credentials, such as the Tree Risk Assessment Qualification (TRAQ) and Board Certified Master Arborist (BCMA) were not identified by any institutions. Just under 14% of all respondents indicated no training or workshops were part of operations (**Figure 13**).

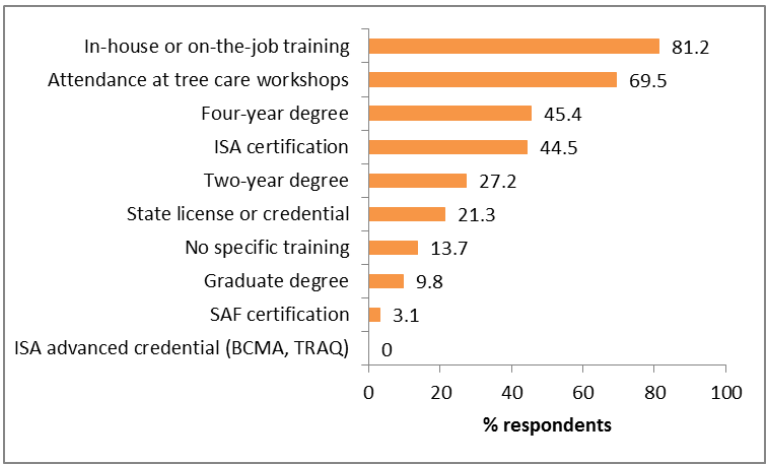

Figure 13. What training and/or credentials are held by staff responsible for tree activities and/or management of trees? (n=357)

Adequacy of Budget

Respondents were asked whether the budget for tree care and maintenance, taken as a percentage of the institution's total budget, has increased, decreased, or stayed about the same over the last 5 years. Overall, over 90% of the respondents indicated their budget has stayed the same (44.7%) or increased (45.6%). Few (9.7%) indicated that their budget had decreased (**no figure shown**). When asked to rate their satisfaction with the budget for tree-related work, over half of all respondents indicated they were satisfied (42.9%) or very satisfied (10.1%) (**Figure 14**). Still, not an inconsequential number of institutions indicated they were unsatisfied (26.9%) or very unsatisfied (5.0%). There didn't appear to be any clear relationship between satisfaction with the budget and change in the allocated budgetary line over the last five years.

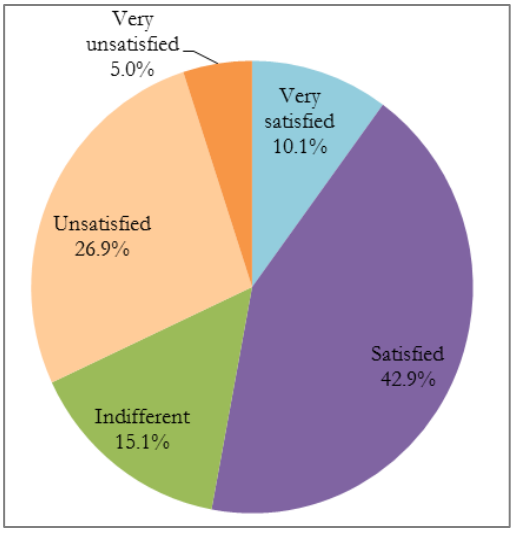

Figure 14. Please rate your satisfaction with the budget for tree-related work. (n=357)

Is the current budget adequate to meet identified needs of current or project future goals? Roughly equal numbers of respondents indicated the budget was adequate (n=179, 50.4%) and *not* adequate (n=176, 49.6%). When examined as a function of institutional group, there were slight differences in the perceptions of budgetary adequacy (**Figure 15**). Four-year private institutions were less optimistic that the budget was adequate while two-year public institutions were the most optimistic (**Figure 15**).

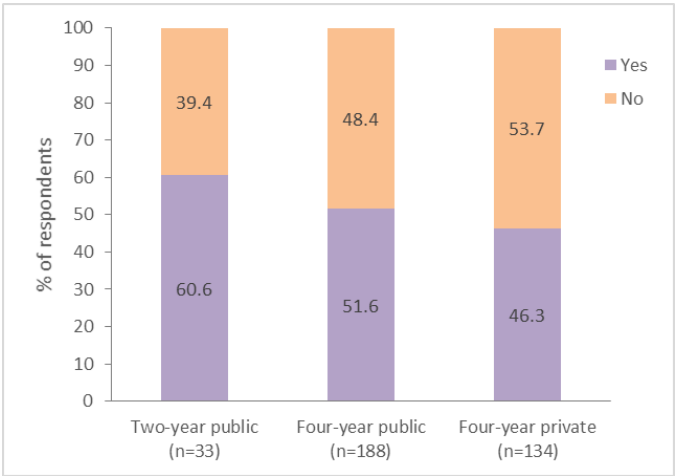

Figure 15. Is your budget adequate to meet the current needs of your work plan or your future goals for tree program activities? (n=355)

SWOT Analysis

A SWOT analysis is a strategic planning method to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project, business venture, or entity such as an institution of higher education or municipality. It generally involves specifying the goals or objectives of the entity (for example, the institutions' tree program goals) and identifying the internal and external factors that are favorable and unfavorable to achieve those objectives.

Respondents were asked to identify the four most significant strengths, weaknesses, opportunities, and threats to their institutions' tree program. For each SWOT category, respondents were given nine to ten potential characteristics and also provided opportunities to write in "other" characteristics.
The SWOT categories were defined in the survey as follows:

- **Strengths**: *Internal* characteristics that are unique, special, highly valued, and/or positive relative to other institution's tree programs.
- **Weaknesses**: *Internal* challenges that limit progress or place the institution at a disadvantage relative to other institution's tree program successes.
- **Opportunities**: *External* elements that could be exploited to accelerate an existing strength of the program, or create and accelerate a new potential strength of the program.
- **Threats**: *External* elements that could cause trouble or could reduce the capabilities and effectiveness of the tree program.

The three most common strengths identified by respondents included the institution's diversity of campus tree species (71.7%), quality of tree care (55.4%), and extent of tree canopy (50.3%) (**Figure 16A**) Other strengths identified included staffing expertise in tree care and management (38.6%), contractor performance/relationship (38%), the institution's comprehensive tree management strategy (24.4%), the institution's engagement of and with community groups and schools (15.4%), the institution's pest management plan (12.3%), the number and diversity of gardens and/or tree orchards (9.3%), and the tree program integration with city plans (6.3%) (**Figure 16A**).

The two most common weaknesses identified by respondents included limited staff (66.1%) and lack of funding/resources (55.5%) (**Figure 16B**). Other weaknesses that were identified included lack of a proactive or planned management (30.0%), lack of tree data, records, and surveys (29.4%), lack of technical expertise in tree care (23.6%), and lack of integrated management with other programs and plans (21.8%), among others (see **Figure 16B**).

In many ways in response to the weaknesses identified by respondents were the opportunities that could be exploited to accelerate an existing or potential new strength of the program. Thus, paralleling the weaknesses were the five most common opportunities identified by respondents including increased funding and resources (61.9%), increased staffing (46.2%), improved data, records, and surveys (43.8%), production of a more proactive tree management plan (42.6%), and improved staff skills (37.5%) (**Figure 16C**). Other opportunities that were identified included an improved inspection regime (24.3%), more computerized management (21.9%), enhancing the treescape quality (17.7%), enhancing the treescape extent (13.2%), and production of an integrated pest management plan (11.4%) (**Figure 16C**).

Finally, the most common threats identified by respondents, that could cause trouble or could reduce the capabilities and effectiveness of the tree program, included funding and resources (66.2%), spread of pests

(53.5%), staff numbers (44.7%), and development conflicts (41.7%) (**Figure 16D**). These were followed by climate change (26.3%), lack of institutional support (22.4%), weak integration with other plans and programs (16.3%), and vandalism (5.1%) (**Figure 16D**).

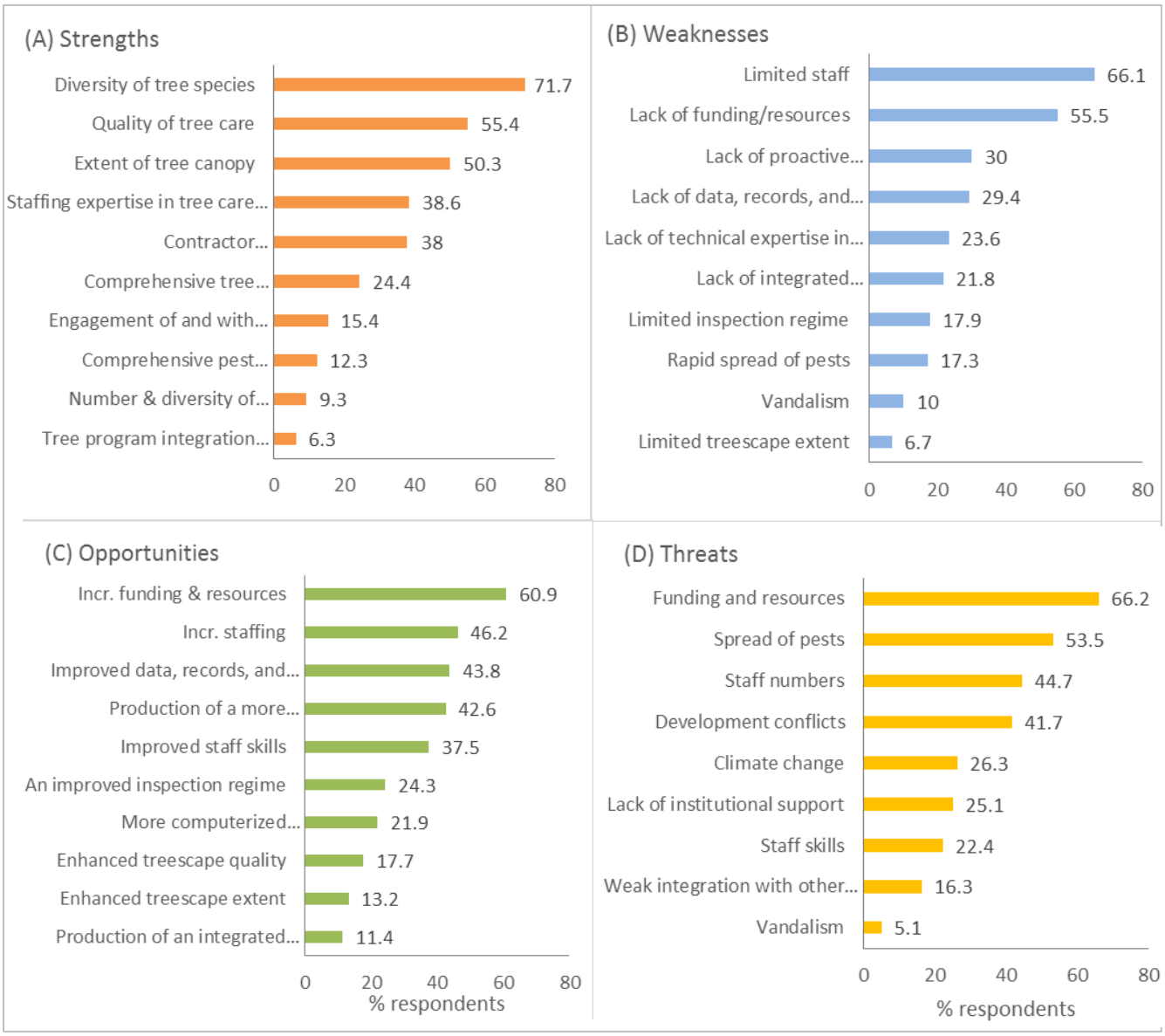

Figure 16. A. What strengths do you think are unique, special, valued, and/or positive relative to other institution's tree programs? B. What weaknesses may limit progress or place the institutions at a disadvantage relative to other institutions' tree program successes? C. What opportunities could be exploited to accelerate an existing strength, or create a new potential strength, of the tree program? D. What external threats do you think could cause trouble or reduce the capabilities and effectiveness of the tree program?

Synthesis of Findings and Recommendations

Trees provide a number of benefits to the character, aesthetics, sustainability, and livability of college campuses. Many campuses are borne out of a pastoral legacy and are home to remnant forests and some old-growth trees that are now situated among a diverse assemblage of planted trees. Deciduous shade trees such as maples, oaks, elms, and sycamore are often interspersed with beautiful flowering trees – redbud, dogwood, cherry – and towering conifers such as spruces, pines, and firs.

As college campuses continue to grow and in many cases become more urbanized, there is a need to understand the forest assets that reside on campus. Many universities are making commitments to campus sustainability efforts, and through carbon sequestration, air pollution abatement, reduction of stormwater runoff, provision of habitat for animals, and improved building energy conservation, campus trees can help both the economic and environmental bottom line of universities. As recent research has demonstrated, trees may also play an important role in shaping the health and well-being of students, faculty, staff, and community members.

To sustain the character and contributions of campus trees requires careful planning, management, and stewardship. Described below are several considerations for colleges and universities which are based on findings in this report, the urban forest sustainability literature (see Clark *et al.* 1997; Kenney *et al.* 2011), and a forest inventory report from Virginia Tech (see Stewart and Wiseman 2018). These considerations are neither exhaustive nor do they represent an endorsement of one action over another. To the latter point, we recognize there are limitations to providing recommendations based on information from 378 institutions. There are 4,600-plus colleges and universities in the U.S. and Canada, and an associated wide variety of geographic settings, growing conditions, available planting spaces, and institutional support (funding and personnel) for managing and sustaining campus tree populations. Therefore, the set of recommendations below are complimented by the work of other scholars in the urban forestry field, and contextualized to the campus landscape. To optimize the benefits of campus trees, the recommendations should be approached by institutions comprehensively, rather than piecemeal, and we intend for the recommendations to be applicable to institutions of any size, even with the most limited of budgets. While local circumstances differ, campus forests often face similar challenges, from pests to invasive species to inadequate growing spaces to budgetary constraints. Using a comprehensive set of strategies may help improve the benefits trees provide over time, and guide effective management and stewardship of campus trees.

[1] Comprehensive tree inventory

Conducting a comprehensive tree inventory is an integral step toward understanding the existing resource base, and the opportunities and constraints for growth in the future. Tree inventories have a range of possible uses, including (but not limited to): (1) assessment of species composition, diversity, and age structure, (2) modeling building energy savings, avoided runoff, air pollution removal, and carbon sequestration, and (3) quantifying tree health, structure, and susceptibility to pests. These analyses – used separately or cumulatively – can aid landscape planning efforts, including the strategic planting and preservation of trees or stands of trees. Of the 378 participating institutions in this study, two-thirds indicated they have some level of a tree inventory – the extent to which these inventories maintain information for *all* or just a *portion* of the campus landscape is unknown. The attributes collected in the tree inventories by institutions varied. Nearly all participants identified tree species and geo-located the identified trees. Just over two-thirds collected tree diameter and condition information, with a smaller portion of the participants collecting information on tree conflicts, risks, value, and insect/disease problems.

To be most successful, a comprehensive tree inventory should include *all* campus trees – planted and emergent – that are greater than a designated size, for example, 1" diameter-at-breast height (DBH) (Martin *et al.* 2011). Collection of attribute data that extends beyond tree species and location, such as dimensional measurements (height and diameter), site variables, health and structure ratings, and maintenance recommendations will help with modeling efforts (for example, using i-Tree tools) and planning efforts. Inventories can be time-intensive and therefore costly, so early efforts should be made to identify how the inventory data will be used. If one of the intended outcomes is to model the carbon sequestration and stormwater abatement benefits of campus trees, then aligning sampling approaches with the Forest Service's i-Tree *Eco* program, for example, should be performed prior to the start of data collection. The extent to which additional attributes are collected will depend on institutional and project goals.

Inventory data and analysis can provide a foundation for crafting a detailed management plan (Stewart and Wiseman 2018); however, it's important to recognize some of the limitations of tree inventories. For example, inventories may be completed – at least in part – by untrained professionals (e.g., students) and they constitute a one-time "snapshot", which may limit the ability of staff to track and assess the health and structural integrity of trees over time. Trees change through the seasons and are subject to different stressors from month to month, year to year. For newly planted trees, systematic assessment of tree metrics by way of tree "re-inventories" may help universities track tree growth and condition, and optimize the allocation of (often limited) support of tree planting and maintenance efforts. There is no widely established "rule" in the urban forestry field dictating the period of time by which trees should be reinventoried (every 3 years? 5 years? 10 years?), but if resources are available, every 3 to 5 years could be an appropriate target.

[2] Tree canopy cover assessment

A complementary assessment to field tree inventories is a tree canopy cover assessment, particularly for campuses that cover large geographic areas. Canopy cover assessments are most commonly determined from analysis of aerial photographs, satellite imagery, fine-resolution images captured by drones, or some combination of these sources. Algorithms (unsupervised or supervised) are employed to classify image pixels into pre-determined land cover classes, such as tree canopy, non-tree vegetation, water, and impervious surface and buildings, though the number and delineation of classes will vary by geographic area and project goals. Where possible, institutions could examine not only their current or "actual" canopy cover, but also their maximum "potential" canopy cover (Kenney *et al.* 2011) which gives a better account of tree cover relative to available plantable space.

Tree canopy assessments can help decision-makers better understand the current amount and spatial arrangement of tree resources. They can also be used to identify locations where trees *can* be planted, to track changes in tree canopy over time, and to specify long-term canopy cover goals. This survey project found that just ~9% of responding institutions currently have a tree canopy goal, another 12% are in the process of identifying one. With greater availability of remote sensing technology, including finer-resolution satellite imagery, campus tree canopy cover assessments may become more common. Ideally, tree canopy cover assessments should be conducted no less than once every five years to best track changes in urban forest extent (Stewart and Wiseman 2018).

[3] Enhanced tree planting

The long-term provision of ecosystem services depends on having a strong, sustained effort of annual tree planting to maintain adequate stocking and canopy cover. In this study, 20% of responding institutions

currently have a tree planting goal; another 16% are in the process of developing one. There is no *one* universal way to establish and identify a tree planting goal, and in this survey study, institutions identified a variety of approaches. Some provided a final tree planting count to be achieved by a given date (e.g., 100 trees by 2022); others a certain number of trees planted each year (e.g., 15 trees per year for 20 years); and others a goal based on replacement (e.g., one for one replacement).

Inventory data (see Recommendation #1) can be used to strategically plan current *and* future locations of tree planting efforts, as well as track locations of attrition. Ideally such plans would be crafted to go beyond planting in vacant spaces and routine tree planting efforts associated with capital projects (Stewart and Wiseman 2018). Rather, more systematic planning of tree planting efforts, including *where* to plant, *what* to plant, and *how* the tree will be maintained to optimize its role in the ecosystem should be considered.

[4] Strategic planting to enhance diversity, resilience, and functionality

Plant more trees, but *which* trees should be planted? Maintaining a diverse mix of trees that are suitable to the growing environment *and* to the desired function at the site is critical to promoting a healthy and resilient urban forest (Kenney *et al.* 2011). Thus, future stocking of the campus forest should give consideration to planting a diverse mix of species that are proven performers on campus, and that are resilient to pests, weather, and other known stressors in the area (Stewart and Wiseman 2018). Though this will certainly vary by location and environmental context, efforts should be made to plant and maintain a diverse age distribution of trees (Kenney *et al.* 2011) and a reasonable mix of small-, medium- and large-maturing species (Stewart and Wiseman 2018). Collectively, these recommendations aim to optimize the provisioning of ecosystem services and minimize maintenance costs.

Campus forests are increasingly being recognized for the ecosystem services and functions they provide, findings which are supported by student projects, and enhanced through certification opportunities like the Arbor Day Foundation's Tree Campus USA program. However, as demonstrated in this study, decisions regarding tree planting commonly focus on beauty and aesthetic value (see Figure 9). Though the "value" assigned to a given campus tree depends on species, where they are, and how big they are, recognition of the *services* that trees provide should be given consideration, particularly as capital projects are planned. A tree planting policy that promotes planting two trees for every one tree removed, while seemingly positive, fails to recognize the ecological value of the tree being removed, which is particularly problematic if the tree is in good health and has a well-established canopy. Creating a culture of campus forest stewardship and sustainability that goes beyond beautification to include helping achieve goals for carbon neutrality, stormwater management, and provision of pollinator habitats better recognizes the vital role trees play in the campus ecosystem.

[5] Cradle-to-cradle tree management approach

Tree removals on campus are a regular part of tree maintenance. In this survey study, respondents indicating removing trees for a variety of reasons, most commonly because of tree death, insect or disease problems, conflict with a capital project, or storm damage (see Figure 10). Tree "waste", including the logs, brush, stumps, and chips generated using arboricultural practices, can be disposed of in many ways. In cities across the U.S., surveys from the 1990s and early 2000s indicate that most urban forest "waste" has traditionally been shipped and disposed of in landfills rather than utilized as a renewable natural resource (Bratkovich *et al.* 2008). In this study, approximately 25% of respondents indicated disposing of tree waste in landfills (see Figure 11). Many institutions also recovered tree waste for mulch, firewood, and lumber for re-use either on- or off-campus.

Tree removal practices, including the disposal of tree waste, can be costly. Because the expansion and densification of college campuses may bring with it loss of tree cover, efforts should be made to close the proverbial loop and support a cradle-to-cradle system whereby "waste" products from felled trees are re-utilized. The idea of wood re-utilization and up-cycling is drawing more and more attention from researchers, arborists, municipalities, woodworkers, campus facilities, and more. Some institutions currently have established re-purposing programs, including on-campus sawmills, kilns, and other equipment to support the programs (see for example, Michigan State University's Shadows Collection here https://msushadows.com/). Such programs can readily engage students in hands-on experience and training concerning a wide range of issues, from urban forestry to arboriculture to waste management to sustainability. Regardless of having resources and equipment available on campus, an effective campus wood waste program would treat felled wood as a usable, and sometimes marketable, product. Careful reuse and recycling can reduce disposal costs and reduce the environmental consequences of tree felling (e.g., lost carbon to the atmosphere).

[6] Opportunities for staff training and attainment of specialized credentials

In this survey study, the two most commonly identified ways to improve institution's tree care programs included greater funding/resources and more staff (see Figure 16). To oversee management of campus forests in a comprehensive, systematic manner requires staff with necessary training and qualifications, and adequate resources available to support staff. How many staff are required to optimize tree care? In this survey study, responding institutions varied from having fewer than one full-time equivalent staff member to having 70 staff members involved in tree care and maintenance. The average number of employees working with trees on a full-time basis was five, though this number should not be used in any prescriptive way as it tells us little about staffing relative to institutional enrollment, campus area, tree density, or other like. To that end, defining an "optimal" number of employees who are involved in campus tree care is tricky as it varies among institutions, making staffing an inappropriate benchmark. Perhaps a better criterion would seek to address training, skill, and experience of facilities staff.

The science and practice of arboriculture has advanced considerably in recent years, and there are now a number of standards, best management practices (BMPs), and credentials that could be employed to advance tree care practices on campus. For example, the standard of care for managing tree *risk* in urban areas is informed by the A300-Part 9 standard for tree risk assessment of the American National Standards Institute, which is complemented by a BMP manual published by the International Society of Arboriculture (ISA) that lays out how to identify, analyze, evaluate, and manage tree risk (Stewart and Wiseman 2018). Finally, the ISA offers a specialized credential to Certified Arborists who complete a two-day course and pass a competency exam called the Tree Risk Assessment Qualification (TRAQ). While many aspects of tree care likely fall within the capabilities of grounds staff, certain aspects of risk, pest, and construction management may require advanced training and skill sets. In this survey study, a large proportion of the training and credentials held by staff at responding institutions were on-the-job and from attendance at tree care/management workshops (see Figure 13). The most commonly pursued certification among responding institutions was the ISA Certified Arborist program (45%), followed by a state-specific license or credential program (21%). None of the responding institutions currently has staff with advanced ISA credentials, such as the TRAQ or Board Certified Master Arborist (BCMA).

Increasing opportunities for staff training and attainment of specialized credentials is recommended. Because a broad range of skills and experience are required to sustainably and optimally manage campus

forests, recognizing and supporting opportunities for staff to enhance their skill set and stay informed of current BMPs, standards, and practices is needed. Where possible, employing a Certified Arborist whose sole responsibility is to oversee the comprehensive and systematic management of the campus forest may also be beneficial. Finally, budgetary allocations that align with the asset value of campus trees should be made to the grounds division. Tree inventory data and the modeling of ecosystem services will enable institutions to better capture the ecological value of campus trees.

Interestingly, respondents of this survey study were split in their attitudes toward their budgetary allocations. Roughly half of all respondents indicated they were satisfied with their current budget; one-third were dissatisfied, and the remaining were indifferent (Figure 14). Roughly half of responding institutions indicated their budget was adequate to meet identified needs of current and future projects, while the remaining half indicated their budget was *not* adequate (Figure 15). There are many competing interests for campus grounds maintenance efforts which can limit or constrain available resources for tree care and protection. Without adequate resources, sufficient maintenance and systematic care of campus trees cannot be performed which can lead to a triage-oriented, reactive approach to tree management. Thus, efforts to align budgetary allocations to the value of campus trees – economic and environmental – should be made.

[7] Campus tree care plans that promote comprehensive, systematic management

Following the need for greater funding/resources and staff, a large percentage of participating institutions identified needing a proactive tree management plan (see Figure 16). Such a plan would ideally be comprehensive in identifying proactive and planned *systematic* ways (as opposed to reactionary ways) to manage the campus tree resource.

A good first step toward developing a comprehensive tree management plan could be modeled after the Arbor Day Foundation's Tree Campus USA "Campus Tree Care Plan" standard. This standard posits that a Tree Care Plan should be goal-oriented, education-oriented, and provide clear guidance for planting, maintaining, and removing trees. At a minimum, a Tree Care Plan must include: (a) a clearly stated purpose, (b) responsible authority figure(s) to enforce the Tree Care Plan, (c) establishment of a campus tree advisory committee, (d) policies for planting, landscaping, maintenance, removing, and managing trees for catastrophic events, (e) protection and preservation policies and procedures, (f) goals and targets for tree canopy, inventory, or similar, (g) procedures to assess tree damage, (h) prohibited practices, (i) definitions of terminology related to campus trees, and (j) a communication strategy (see https://www.arborday.org/programs/treecampususa/standards.cfm).

A tree management plan should also lay out strategies to monitor and plan for diseases and pests. In the eastern U.S., many institutions having ongoing programs to manage Dutch elm disease, emerald ash borer, hemlock woolly adelgid, and needlecast disease, but there are other noxious pests that could impact a substantial number of campus trees in the near future. Minimizing impacts requires early detection and rapid response, which in turn requires frequent monitoring (Steward and Wiseman 2018). Incorporating a detection and response strategy in a tree care plan may enable resources to be more readily accessible for deployment in the event of an outbreak.

To be most successful, immediate and future plans for tree care should be incorporated into campus master plans. Commitment and support from leadership toward tree and forest stewardship will promote greater recognition of the important role trees play on campus, and the ways in which students, faculty, staff, and community members can interact with and benefit from campus trees.

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Appendix I. Participating Institutions (in alphabetical order and abbreviated when needed to conserve space). Categories denote the following institutional categories used throughout the report: two-year public institutions (PU2), four-year public institutions (PU4), and four-year private institutions (PR4).

Institution	State	CATEG.
Abilene Christian University	TX	PR4
Aims Community College	CO	PU2
Alcorn State University	MS	PU4
Algonquin College	Ontario	PU4
Allegheny College	PA	PR4
American University	DC	PR4
Anne Arundel Community College	MD	PU2
Appalachian State University	NC	PU4
Arizona State University Tempe	AZ	PU4
Arizona State University West	AZ	PU4
Arizona State University-Downtown	AZ	PU4
Arkansas State University ain	AR	PU4
Arkansas Tech University	AR	PU4
Art Center College of Design	CA	PR4
Auburn University	AL	PU4
Augustana College	IL	PR4
Austin Peay State University	TN	PU4
Ball State University	IN	PU4
Bellarmine University	KY	PR4
Bellevue University	NE	PR4
Berea College	KY	PR4
Boise State University	ID	PU4
Boston College	MA	PR4
Bradley University	IL	PR4
Bridgewater State University	MA	PU4
Brigham Young University - Idaho	ID	PR4
Bryant University	RI	PR4
Bucknell University	PA	PR4
Butler County Community College	PA	PU2
Cabrini University	PA	PR4
California Baptist University	CA	PR4
California Institute of Technology	CA	PR4
Cal Poly, San Luis Obispo	CA	PU4
CSU Northridge	CA	PU4
CSU of Fullerton	CA	PU4
CSU San Bernardino	CA	PU4
CSU Stanislaus	CA	PU4
CSU Chico State	CA	PU4
CSU Bakersfield	CA	PU4
CSU East Bay	CA	PU4
CSU Long Beach	CA	PU4
Calumet College of St. Joseph	IN	PR4
Calvin College	MI	PR4
Campbell University	NC	PR4
Capilano University	Brit. Col.	PU4
Carleton University	Ontario	PU4
Carnegie Mellon University	PA	PR4
Casper College	WY	PU2
Cedar Crest College	PA	PR4
Central Oregon Community College	OR	PU2
Central Wyoming College	WY	PU2
Chadron State College	NE	PU4
Chatham University	PA	PR4
Claremont McKenna College	CA	PR4
Clarkson University	NY	PR4
Clemson University	SC	PU4
Cleveland State University	OH	PU4

Institution	State	CATEG.
Pepperdine University	CA	PR4
Pittsburg State University	KS	PU4
Polk State College	FL	PU4
Portland Community college	OR	PU2
Princeton University	NJ	PR4
Purdue University	IN	PU4
Quinnipiac University	CT	PR4
Reed College	OR	PR4
Regent University	VA	PR4
Regis University	CO	PR4
Rhode Island College	RI	PU4
Rhodes College	TN	PR4
Rice University	TX	PR4
Ripon College	WI	PR4
Robert Morris University	PA	PR4
Roberts Wesleyan College	NY	PR4
Rochester Institute of Technology	NY	PR4
Rose-Hulman Instit. of Techn.	IN	PR4
Saginaw Valley State University	MI	PU4
Saint Ambrose University	IA	PR4
Saint Cloud State University	MN	PU4
Saint Mary's University of Minn.	MN	PR4
Salisbury University	MD	PU4
Salt Lake Community College	UT	PU2
Sam Houston State University	TX	PU4
San Diego State University	CA	PU4
Santa Clara University	CA	PR4
Savannah State University	GA	PU4
Sewanee-University of the South	TN	PR4
Shepherd University	WV	PU4
Sheridan College	WY	PU2
Sierra College	CA	PU2
Simpson College	IA	PR4
Sinclair Community College	OH	PU2
Slippery Rock University of PA	PA	PU4
Smith College	MA	PR4
Soka University of America	CA	PR4
South Dakota State University	SD	PU4
Southern Arkansas Univ. - Main	AR	PU4
Southern Oregon University	OR	PU4
Southern Utah University	UT	PU4
Southern Virginia University	VA	PR4
Southwest Minn. State University	MN	PU4
Southwestern University	TX	PR4
Spelman College	GA	PR4
St Catherine University	MN	PR4
St. Olaf College	MN	PR4
SUNY at New Paltz	NY	PU4
SUNY at Purchase College	NY	PU4
SUNY Buffalo State	NY	PU4
SUNY College at Cortland	NY	PU4
SUNY College at Geneseo	NY	PU4
Susquehanna University	PA	PR4
Swarthmore College	PA	PR4
Taylor University	IN	PR4
Tech. College of the Lowcountry	SC	PU2
Temple University	PA	PU4

Coe College	IA	PR4
Colby College	ME	PR4
Colby awyer College	NH	PR4
College of Southern Nevada	NV	PU4
College of William and Mary	VA	PU4
Collin County Comm. College District	TX	PU2
Colorado College	CO	PR4
Colorado State University-Fort Collins	CO	PU4
Columbia Basin College	WA	PU4
Columbus State University	GA	PU4
Community College of Allegheny Cty	PA	PU2
Cornell University	NY	PR4
Cornerstone University	MI	PR4
County College of Morris	NJ	PU2
Covenant College	GA	PR4
Creighton University	NE	PR4
CUNY Lehman College	NY	PU4
Dakota State University	SD	PU4
De Anza Community College	CA	PU2
Denison University	OH	PR4
Doane Univ.-College of Prof. Studies	NE	PR4
Dominican University	IL	PR4
Drew University	NJ	PR4
Drury University	MO	PR4
Duke University	NC	PR4
Earlham College	IN	PR4
East Carolina University	NC	PU4
East Tennessee State University	TN	PU4
Eastern Illinois University	IL	PU4
Eastern Mennonite University	VA	PR4
Eastern University	PA	PR4
Eckerd College	FL	PR4
Elizabethtown College	PA	PR4
Emory & Henry College	VA	PR4
Emory University	GA	PR4
Evangel University	MO	PR4
Fanshawe College	Ontario	PU4
Florida Institute of Technology	FL	PR4
Florida State University	FL	PU4
Fort Hays State University	KS	PU4
Franciscan University of Steubenville	OH	PR4
Georgetown University	DC	PR4
Georgia College & State University	GA	PU4
Georgia Institute of Technology	GA	PU4
Georgia Southern University	GA	PU4
Goshen College	IN	PR4
Goucher College	MD	PR4
Governors State University	IL	PU4
Grand Rapids Community College	MI	PU2
Grand Valley State University	MI	PU4
Guilford College	NC	PR4
Hamilton College	NY	PR4
Haverford College	PA	PR4
Hillsdale College	MI	PR4
Hiram College	OH	PR4
Hope College	MI	PR4
Howard Payne University	TX	PR4
Idaho State University	ID	PU4
Illinois State University	IL	PU4
Indiana State University	IN	PU4
Indiana University-Bloomington	IN	PU4
IUPUI	IN	PU4

Texas A&M Univ. - Commerce	TX	PU4
Texas Christian University	TX	PR4
Texas State University	TX	PU4
Texas Women's University	TX	PU4
The College of New Jersey	NJ	PU4
The College of Wooster	OH	PR4
The Univ. of Alabama	AL	PU4
The Univ. of TN - Knoxville	TN	PU4
The Univ. of TN - Martin	TN	PU4
The Univ. of Texas at Austin	TX	PU4
The Univ. of Texas at Dallas	TX	PU4
The Univ. of Texas at El Paso	TX	PU4
The Univ. of Texas at Tyler	TX	PU4
UTMDACC	TX	PU4
Thiel College	PA	PR4
Towson University	MD	PU4
Trine University	IN	PR4
Truman State University	MO	PU4
Tufts University	MA	PR4
Union College chenectady	NY	PR4
University at Buffalo	NY	PU4
University of Akron	OH	PU4
Univ. of Alabama in Huntsville	AL	PU4
University of Alaska Anchorage	AK	PU4
University of Alaska Fairbanks	AK	PU4
University of Alaska Southeast	AK	PU4
University of Alberta	Alberta	PU4
University of Arizona	AZ	PU4
University of Arkansas	AR	PU4
Univ. of Arkansas at Little Rock	AR	PU4
Univ. of AR for Medical Sciences	AR	PU4
Univ. of Arkansas-Fort Smith	AR	PU4
University of British Columbia	Brit. Col.	PU4
University of Calgary	Alberta	PU4
University of California, Irvine	CA	PU4
University of California-Berkeley	CA	PU4
University of California A	CA	PU4
Univ. of California an Francisco	CA	PU4
University of Central Arkansas	AR	PU4
University of Central Florida	FL	PU4
University of Charleston	WV	PR4
University of Colorado Boulder	CO	PU4
University of Denver	CO	PR4
University of Florida	FL	PU4
University of Georgia	GA	PU4
University of Hawaii Manoa	HI	PU4
Univ. of Houston-Downtown	TX	PU4
University of Idaho	ID	PU4
University of Illinois at Chicago	IL	PU4
University of Iowa	IA	PU4
University of Kentucky	KY	PU4
University of Lethbridge	Alberta	PU4
University of Maine	ME	PU4
Univ. of Maryland College Park	MD	PU4
Univ. of Massachusetts Amherst	MA	PU4
University of Memphis	TN	PU4
Univ. of Michigan-Ann Arbor	MI	PU4
University of Michigan-Dearborn	MI	PU4
University of Michigan-Flint	MI	PU4
Univ. of Minnesota Twin Cities	MN	PU4
University of Minnesota orris	MN	PU4
University of Mississippi	MS	PU4

IPFW	IN	PU4
Indiana University outh Bend	IN	PU4
Iowa State University	IA	PU4
James Madison University	VA	PU4
John Carroll University	OH	PR4
Johns Hopkins University	MD	PR4
Judson College	AL	PR4
Kankakee Community College	IL	PU2
Kansas State University	KS	PU4
Kennesaw State University	GA	PU4
Kent State University at Kent	OH	PU4
Kentucky State University	KY	PU4
Kenyon College	OH	PR4
Kettering University	MI	PR4
Keuka College	NY	PR4
Kutztown University	PA	PU4
Lakeland College	WI	PR4
Lakeland College	Alberta	PU2
Lander University	SC	PU4
Laramie County Community College	WY	PU2
Lawrence Technological University	MI	PR4
Le Moyne College	NY	PR4
Lehigh University	PA	PR4
Lewis & Clark College	OR	PR4
Liberty University	VA	PR4
Longwood University	VA	PU4
Louisiana State University	LA	PU4
Loyola University Maryland	MD	PR4
Luther College	IA	PR4
Macalester College	MN	PR4
Maine Maritime Academy	ME	PU4
McHenry County College	IL	PU2
McMaster University	Ontario	PU4
Medical University of South Carolina	SC	PU4
Merced College	CA	PU2
Meredith College	NC	PR4
Middlesex County College	NJ	PU2
Midwestern University	IL	PR4-G
Mississippi State University	MS	PU4
Mississippi University for Women	MS	PU4
Missouri Univ. of Science and Techn.	MO	PU4
Montana State University	MT	PU4
Moravian College	PA	PR4
Morehouse College	GA	PR4
Morgan State University	MD	PU4
Mount St. Mary's University	CA	PR4
Muhlenberg College	PA	PR4
Muskingum University	OH	PR4
Nash Community College	NC	PU2
New Jersey City University	NJ	PU4
New Orleans Baptist Theol. Seminary	LA	PR4
Norfolk State University	VA	PU4
North Carolina State University	NC	PU4
North Central College	IL	PR4
North Dakota State College of Science	ND	PU2
North Dakota State University	ND	PU4
North Lake College	TX	PU2
North Park University	IL	PR4
Northern Kentucky University	KY	PU4
Northwestern Michigan College	MI	PU4
Nova Southeastern University	FL	PR4
Ohio State University ain Campus	OH	PU4
Oklahoma City Community College	OK	PU2

Univ. of Missouri-Kansas City	MO	PU4
University of Missouri t. Louis	MO	PU4
University of Nebraska at Omaha	NE	PU4
University of Nebraska incoln	NE	PU4
University of Nevada asVegas	NV	PU4
University of New Mexico ain	NM	PU4
UNC Asheville	NC	PU4
UNC at Chapel Hill	NC	PU4
UNC at Greensboro	NC	PU4
UNC Charlotte	NC	PU4
UNC Wilmington	NC	PU4
University of North Florida	FL	PU4
University of North Texas	TX	PU4
University of Northern Colorado	CO	PU4
University of Northern Iowa	IA	PU4
University of Notre Dame	IN	PR4
University of Pennsylvania	PA	PR4
Univ. of Pittsburgh-Pittsburgh	PA	PU4
Univ. of Prince Edward Island	PEI	PU4
University of Puget Sound	WA	PR4
University of Redlands	CA	PR4
University of Richmond	VA	PR4
USC-Columbia	SC	PU4
University of South Dakota	SD	PU4
University of South Florida ain	FL	PU4
University of Southern California	CA	PR4
Univ. of Southern Mississippi	MS	PU4
University of St. Thomas	MN	PR4
University of Toledo	OH	PU4
University of Vermont	VT	PU4
University of Virginia ain	VA	PU4
University of Washington eattle	WA	PU4
University of West Georgia	GA	PU4
UW a Crosse	WI	PU4
UW adison	WI	PU4
UW ilwaukee	WI	PU4
University of Wyoming	WY	PU4
Utah State University	UT	PU4
Vanderbilt University	TN	PR4
Vassar College	NY	PR4
Villanova University	PA	PR4
Virginia Commonwealth Univ.	VA	PU4
Virginia Military Institute	VA	PU4
Virginia Tech	VA	PU4
Virginia Western Comm. College	VA	PU2
Viterbo University	WI	PR4
Volunteer State Comm.y College	TN	PU2
Wake Forest University	NC	PR4
Walsh College	MI	PR4
Washington and Lee University	VA	PR4
Washington College	MD	PR4
Washington State University	WA	PU4
Washtenaw Community College	MI	PU2
Waubonsee Community College	IL	PU2
Wellesley College	MA	PR4
Wentworth Institute of Tech.	MA	PR4
West Chester University	PA	PU4
Western Illinois University	IL	PU4
Western Michigan University	MI	PU4
Western Washington University	WA	PU4
Wharton County Junior College	TX	PU2
Wheaton College-Wheaton	IL	PR4
Whitman College	WA	PR4

Old Dominion University	VA	PU4
Oregon State University	OR	PU4
Pacific Lutheran University	WA	PR4
Pacific Union College	CA	PR4
Palomar College	CA	PU2
Passaic County Community College	NJ	PU2
Pennsylvania State University ain	PA	PU4

Willamette University	OR	PR4
William Paterson Univ. of NJ	NJ	PU4
Winona State University	MN	PU4
Worcester State University	MA	PU4
Wor-Wic Community College	MD	PU2
Youngstown State University	OH	PU4
Yukon College	Yukon	PU2