arnoldia

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Inside back cover: This magnificent specimen (accession 5883-A) of Sargent oak (*Quercus* x *sargentii*) crowns the State Lab Slope area at the Arnold Arboretum. Photo by Nancy Rose.

Tree by Tree, Yard by Yard: Replanting Worcester's Trees

Mollie Freilicher

The trees of Worcester, Massachusetts, have had a hard time recently, as Asian longhorned beetle (ALB) (*Anoplophora glabripennis*) has decimated public and private trees there and in surrounding communities. What may be less well known is that the invasion of ALB is just the most recent blow in what has been a difficult century for trees in the Worcester area. Some of the issues that the city has faced, such as canopy defoliation from gypsy moth (*Lymantria dispar*) and tree death from chestnut blight (*Cryphonectria parasitica*) and Dutch elm disease (*Ophiostoma ulmi*), were not unique to Worcester, affecting many communities across the eastern and central United States. Other threats have been more localized. Worcester, along with much of New England, suffered major tree loss in the 1938

Disasters have hit Worcester's trees before, including the devastating 1953 tornado. Photo of tornado damage by Alfred K. Schroeder, June 1953.

MICHAEL BOHNE, BUGWOOD.ORG

PA DEPT. OF CONSERVATION AND NATURAL RESOURCES, BUGWOOD.ORG

An adult male Asian longhorned beetle. ALB larvae tunnel into host trees, damaging essential conductive tissues. After pupating, adult beetles emerge from large, round exit holes, as seen on this maple trunk.

hurricane, and a tornado in 1953 devastated parts of Worcester. More recently, the ice storm of 2008 damaged many trees, some beyond recovery, in the Worcester area. The ongoing onslaught has made it difficult for planting efforts to keep up with tree losses.

Following the 1953 tornado and the already significant losses from Dutch elm disease, Worcester began growing maples and ramping up its planting efforts. Maples, especially Norway maple (*Acer platanoides*), known for its urban adaptability, became a mainstay of the planting program. Over the next six decades, maples came to comprise 80% of street trees, leaving many of the city's public trees vulnerable to a maple-specific insect or disease.

Enter Asian longhorned beetle. This maple-loving insect was found in Worcester in August 2008 and has since been detected in four surrounding towns, spurring the creation of a regulated area in Worcester County that now measures 98 square miles. Like the hurricane and tornado, ALB quickly changed the landscape of Worcester's northern neighborhoods. Residents felt bereft of trees and looked to state and federal authorities to come forward with a solution. Even in areas without ALB, communities across the United States have been losing trees to development, to neglect over time, and to a lack of adequate replacement programs. Add up Worcester's experience with the hurricane, the tornado, the ice storm, and ALB, and the importance of replanting becomes clear. On a psychological level, replanting is also an important part of the healing process following the losses to ALB and the ice storm.

Tree Benefits

While urban residents have enjoyed shade and the aesthetic benefits of trees, in the last several decades researchers have studied the ecological, psychological, and social benefits of trees in urbanized areas. It is now known that trees are important for air quality, watershed health, carbon dioxide reduction, soil quality, noise reduction, property values, and psychological and social well-being. Street trees alone in Worcester provide over $2.3 million in annual benefits such as those described above. That is not even counting the thousands of trees in parks, yards, and woodlots across the city. The replacement value for the 17,000 street trees accounted for in a 2006 street tree inventory was close to $100 million. Urban forests are valuable indeed.

KENNETH R. LAW, USDA APHIS PPQ, BUGWOOD.ORG

Granville Avenue in Worcester, Massachusetts, as removal of street trees begins, and the barren view afterwards.

Tree Loss and ALB Protocol

To examine the legacy of the past planting efforts in Worcester, we can look at street trees, often the most visible component of planting programs. The street tree inventory of Worcester identified the distribution of street trees across neighborhoods throughout the city. Neighborhoods with the most street trees also had high numbers of maples: Burncoat, Greendale, Salisbury Forest Grove, and the Salisbury Street area. These areas have close to a thousand or more maple street trees and represent some of the areas with trees most vulnerable to ALB. With ALB in the maple-laden Greendale and Burncoat neighborhoods and with nearby industrial areas and major transit corridors that can serve as entry points and modes for spreading ALB, there was a perfect storm for an infestation of ALB. Since the only way to deal with an infested tree is to cut it down and chip it, there is potential for significant tree loss when ALB is present in high numbers. The density of infested trees in the Greendale and Burncoat areas, and the density of egg sites and exit holes on the infested trees themselves, resulted in the removal of infested trees and surrounding host trees that were also high risk for ALB infestation. The number of infested trees has not reached the soaring levels seen in 2008, but Worcester and the surrounding communities in the regulated area, (Auburn, Holden, West Boylston, Boylston, and Shrewsbury) have all been affected by the beetle and, as of May 2011, over 29,000 trees have been removed.

In the heavily infested Greendale and Burncoat neighborhoods, some residents lost most, if not all, trees from their lots. For many longtime residents, the loss of trees was an emotional experience. Some streets that had been lined with maples quickly became barren. Residents felt the character of their neighborhoods had completely changed. Images of empty streets were reminiscent of pictures following the tornado, when some streets were stripped of all trees. With the losses to ALB and the ice storm, the opportunity arose to reshape the urban forest—to improve diversity by planting a variety of non-host trees (trees that cannot support ALB), to move away from monocultures of maples, to strategically place trees along streets, in parks, and on private property to ensure that they have adequate growing space now and in the future, to educate residents about the value of trees and how to care for and maintain them, and to keep track of the new trees over time. The scale of such a replanting effort was larger than in any of the other ALB infested areas in the United States (parts of New York, Illinois, and New Jersey).

Planning the Plantings

The lead federal agency in the Massachusetts ALB Cooperative Eradication Program is the United States Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) and the lead state agency is the Massachusetts Department of Conservation and Recreation (DCR). Replanting has been a component of all ALB programs in the United States and the United States Forest Service (USFS) is the lead agency for working with cooperators toward this end. Some cooperators in the Worcester area include municipalities and non-profit organizations that have stepped up

MOLLIE FREILICHER

Professional staff, volunteers, and property owners have all been involved in tree replanting efforts. Here a DCR team in Boylston plants trees.

MOLLIE FREILICHER

Trees at the holding yard are loaded for delivery to planting sites.

planting efforts. Congressman Jim McGovern and Lt. Governor Tim Murray founded the Worcester Tree Initiative (WTI) in 2009 with the goal of planting 30,000 trees in the Worcester area over a five-year period. The WTI works toward this goal through tree giveaways, tree plantings, and training programs for volunteers. At tree giveaways, attendees learn how to plant and care for a tree properly before taking home a tree of their choice to plant in their yard. The WTI also works with school volunteers and students to plant trees on school properties and also holds "train the trainer" events to train volunteers in tree planting and care so that they can, in turn, train others and be part of WTI's outreach events.

The City of Worcester has also increased its planting efforts. Since 2009, the city Forestry Division has planted hundreds of new trees along streets. In 2010, the city implemented an "adopt a tree" program to encourage residents whose properties do not have trees, or who have trees vulnerable to disease or insect infestation, to accept a tree planted by the city. The Forestry Division has also worked with the WTI to assist with school and park plantings in Worcester. Municipalities and non-profit organizations work together to ensure that efforts are not duplicated and that each entity reaches out to help replant trees in the area.

In the Worcester area, there have been two government-funded replanting programs that the DCR has administered with federal funds. The two programs share the basic goals of replanting trees and improving diversity, however the execution and scope of the programs differ. The first was a $500,000 program funded by the USDA that began in spring 2009 and wrapped up in spring 2010. The goal of the USDA-funded planting was to mitigate the impact to the communities where host trees were removed because of ALB infestations. The USDA-funded planting specifically targeted property owners who lost trees to ALB in the 2-square mile core area where most removals occurred in 2009. For a property owner to be eligible for a tree with the USDA planting, the owner had to have lost a tree over six inches diameter at breast height (dbh) from a maintained area of the property. This put the focus on replacing landscape and specimen trees on properties in areas where natural regeneration could not be expected. Naturalized, unmaintained areas that could regenerate on their own were not included in this planting. Already two years on, property owners are seeing these areas come back to life.

By spring 2009, the funding was in place from the USDA to plant approximately 800 trees in the areas first affected by tree removals. Properties that lost trees to ALB were identified from the USDA database and DCR foresters mailed information to property owners about replanting. Interested property owners responded and staff scheduled visits to select trees and locations. Additionally, staff went door to door to reach property owners who did not respond.

As the USDA planting program was wrapping up, the next program was just getting started. The American Recovery and Reinvestment Act of 2009 (ARRA) provided $4.487 million in funding for the second planting program that got underway in spring 2010. The ARRA planting will continue into 2012. It targets all property owners in the regulated area regardless of whether they lost a tree to ALB. The only limit to the number of trees a property can have is the number of trees the property could support. In addition to increasing diversity and the number of trees on private property, the ARRA planting aims to restore public shade trees, to plant 15,000 trees on private property, to restore forest canopy and watershed functions affected by reduced canopy, and to create jobs. As of May 16, 2011, over 4,700 trees have been planted through the ARRA program. In addition to working with residents to site trees, DCR foresters also conduct inspections of trees planted in previous seasons to ensure that trees

NANCY ROSE

Though popular ornamental trees, mountain ashes (*Sorbus* spp.) were not offered in replanting programs because of their suscebtibility to ALB. *S. aucuparia* 'Michred' shown here.

Host Genera for Asian Longhorned Beetle

Acer	Maple
Aesculus	Horse chestnut
Albizia	Mimosa
Betula	Birch
Celtis	Hackberry
Fraxinus	Ash
Platanus	Sycamore
Populus	Poplar
Salix	Willow
Sorbus	Mountain ash
Ulmus	Elm
Cercidiphyllum	Katsura tree
Koelreuteria	Goldenrain tree

are establishing adequately. These inspections are also part of a larger data collection effort on the plantings, which will provide valuable information for other communities dealing with ALB and subsequent tree planting efforts.

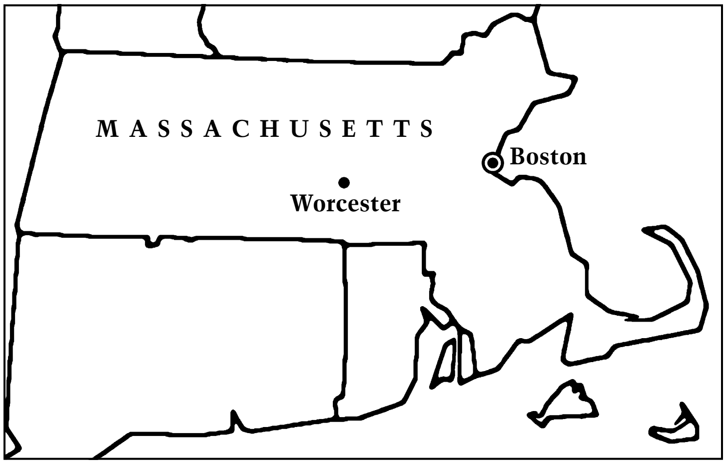
Selecting Species

An early task of the replanting programs was to determine a species list to offer. First and foremost, trees for replanting could not be host trees for ALB. The tree species also had to tolerate urban conditions and be relatively free of insect and disease problems. It was also important to have trees that ranged in size and character at maturity from small ornamental trees to large shade trees and included both deciduous and evergreen species. The species also had to be readily available in large quantities from the nursery, a factor that ruled out some otherwise practical candidates such as Kentucky coffeetree (*Gymnocladus dioicus*) and Serbian spruce (*Picea omorika*). Foresters selected a mix of native and non-native species (see Table 1).

Property owners wanted trees for a variety of reasons, including shade, ornamentation, and privacy, and a diverse list helped meet those needs. With demand high for some species on the list, occasionally some residents had to accept substitutes, especially in the case of cherries (*Prunus* spp.) and crabapples (*Malus* spp.). Demand was so high for some selections that nursery supply could not keep up and these species, including Japanese tree lilac (*Syringa reticulata*) and ginkgo (*Ginkgo biloba*), had to be removed from the planting list. The initial list included 18 species and this list has evolved to include 22 species for the upcoming planting seasons.

ALB Regulated Area

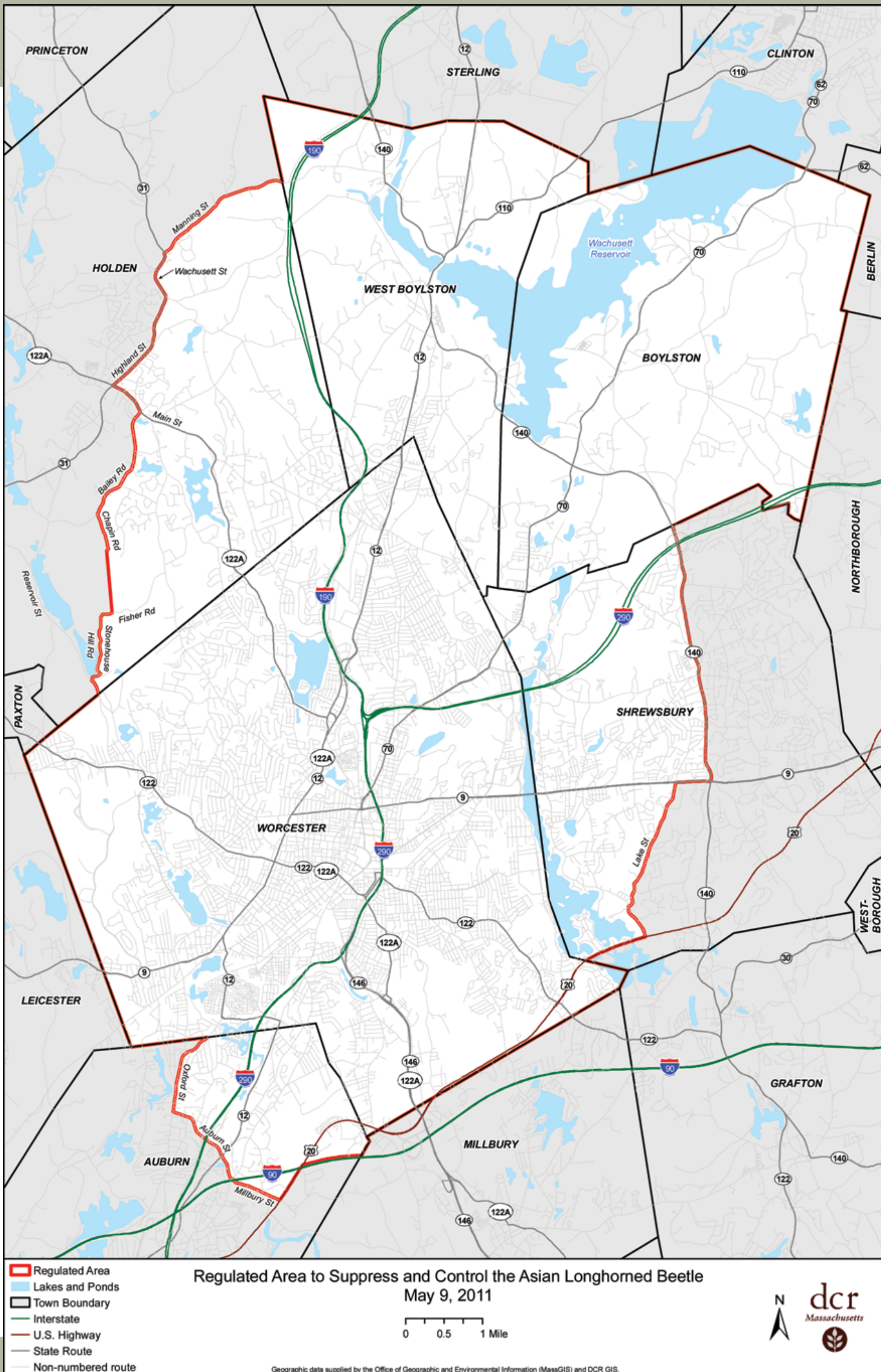
The map on the facing page shows the 98-square-mile regulated area for Asian longhorned beetle infestation in Worcester County. Firewood, green lumber, branches, roots, logs, debris, and nursery stock of host genera is restricted from leaving the regulated area. The boundary is determined by creating a 1.5-mile buffer around infested trees, so as infested trees are found near the edges, the regulated area expands.



Current Infestation Information

The Asian Longhorned Beetle Cooperative Eradication Program is a partnership between the United States Department of Agriculture's Animal and Plant Health Inspection Service and U.S. Forest Service, the Massachusetts Department of Conservation and Recreation, the Massachusetts Department of Agricultural Resources, and the towns and cities of the regulated areas. Chart is current as of May 24, 2011. For up-to-date information on the program go to: http://www.massnrc.org/pests/alb/

	Worcester County	Boston/ Brookline
Current Staff	147	9
Quarantine (Square Miles)	98	10
Infested Trees Removed	19,368	6
High Risk Trees Removed	10,250	0
Trees Planted	5,898	12


PRINCETON
STERLING
CLINTON
HOLDEN
WEST BOYLSTON
BOYLSTON
BERLIN
Wachusett Reservoir
Manning St
Wachusett St
Highland St
Main St
Bailey Rd
Chapin Rd
Fisher Rd
Stonehouse Hill Rd
Reservoir St
PAXTON
NORTHBOROUGH
SHREWSBURY
WORCESTER
Lake St
WEST-BOROUGH
LEICESTER
AUBURN
Oxford St
Auburn St
Millbury St
MILLBURY
GRAFTON
Regulated Area
Lakes and Ponds
Town Boundary
Interstate
U.S. Highway
State Route
Non-numbered route
Regulated Area to Suppress and Control the Asian Longhorned Beetle
May 9, 2011
0 0.5 1 Mile
N
dcr Massachusetts
Geographic data supplied by the Office of Geographic and Environmental Information (MassGIS) and DCR GIS.

Outreach and Property Owner Visits

The outreach from the ALB Cooperative Eradication Program for both planting programs was similar. From the outset, it was important for staff from DCR and APHIS to visit property owners to discuss options for replanting. Many property owners were inexperienced with trees, so a personal visit was important not only to assess properties for tree species suitability but also to educate residents about trees and tree care. With personal visits, we could ensure that the right tree was selected for the right place and, just as importantly, that a tree selected was one that the property owner liked and would maintain. After all, these trees have to survive if they are going to provide enjoyment and benefits into the future. In addition to granting permission for tree planting, property owners signed an agreement stating that they would maintain trees for two years including watering, mulching, and removing stakes if they were used. Residents also were eager to share their experiences with the tree removals and often used the site visits as part of their healing process in their discussions with staff.

MOLLIE FREILICHER

Flowering cherries (*Prunus* spp.) were popular choices for homeowners participating in replanting programs.

NANCY ROSE

Its narrow, upright form makes Serbian spruce (*Picea omorika*) a good choice for urban sites, but it was not readily available from nurseries so could not be offered in the replanting programs.

Learning from Other Replanting Programs

In June 2009, Eric Seaborn, the Program Coordinator for DCR Urban and Community Forestry and Alan Snow, the DCR Community Action Forester, traveled to New York for a workshop on how New York and New Jersey ALB programs conducted their plantings. While Seaborn and others had already devised the basic strategy for the replanting and developed the methodology for both plantings, the workshop granted the opportunity to hear about successes from the New York and New Jersey replanting efforts and to view materials officials there used in outreach. The Worcester




NANCY ROSE (ALL PHOTOS)

Trees selected for the replanting effort include (left to right) seviceberry (*Amelanchier* spp.), tuliptree (*Liriodendron tulipifera*), red oak (*Quercus rubra*), and linden (*Tilia* spp.).

Table 1. Replanting List for Massachusetts Regulated Area.

This represents current and past species that have been offered in the replanting program.

LARGE SHADE TREES	
Carpinus caroliniana	American hornbeam
Cladrastis kentukea (syn. *lutea*)	Yellowwood
Fagus sylvatica	European beech
*Ginkgo biloba**	Ginkgo
Gleditsia triacanthos	Honeylocust
Larix spp.	Larch
Liquidambar styraciflua	Sweetgum
Liriodendron tulipifera	Tuliptree
Metasequoia glyptostroboides	Dawn redwood
Nyssa sylvatica	Blackgum
Ostrya virginiana	American hophornbeam
Quercus alba	White oak
Quercus bicolor	Swamp white oak
Quercus coccinea	Scarlet oak
Quercus palustris	Pin oak
Quercus rubra	Red oak
Tilia spp.	Linden/basswood
ORNAMENTAL TREES	
Amelanchier spp.	Serviceberry
Chionanthus virginicus	Fringetree
Cornus spp.	Dogwood
Malus spp.	Crabapple
Prunus spp.	Cherry
*Syringa reticulata**	Japanese tree lilac
EVERGREEN TREES	
Abies concolor	White fir
Picea pungens	Colorado spruce
Pinus strobus	Eastern white pine
*Thuja occidentalis**	American arborvitae

*No longer offered

area replanting built on those efforts, especially with regard to tree care information that was distributed to residents.

Database and Information Tracking

On top of the planting, diversity, and watershed goals for the USDA and ARRA plantings, DCR is gathering information on the trees planted for a central database. The database includes data from the USDA and ARRA plantings as well as other organizations planting in the regulated area including the WTI and the City of Worcester. With so much planting in the Worcester area, there is a great opportunity to study the fates of newly planted trees in New England communities. Additionally, there will be chances to investigate many aspects of tree planting, establishment, and survival on a large scale.

To keep track of trees, DCR foresters use tablet computers enabled with GPS and sketch-mapping software . The Forest Service provided equipment and technical assistance to adapt software used for forest health monitoring in Massachusetts so that it could be used for the replanting. This software has eased data collection and facilitated the presentation of the planting data. When foresters are on site visits with property owners, the software enables the foresters to see the property on an orthophoto (a type of aerial image used in Geographic Information Systems [GIS]), and drop a point on the map where a tree is to be placed. Once the forester draws the point on the map, a window opens where the forester can enter information on the tree, the property, and the contact information for the property owner. The software then creates a file that is usable in any GIS software. This file contains both the data the foresters have input as well as the spatial data. Foresters use this file to generate the tree order for the nursery. Foresters also use this software to conduct a post-planting inspection. It is this information, the data from the final inspection, that goes into the central database and that will provide a baseline of data on the newly planted trees. Foresters are also beginning to use the USDA Forest Service's i-Tree

MOLLIE FREILICHER

Trees are readied for planting at Quinsigamond Community College during 2009, the first year of the USDA replanting program.

MOLLIE FREILICHER

Data on these recently planted street trees on Fairhaven Road in Worcester will be gathered for a central database that will help evaluate tree establishment and survival.

software to explore the structure of and the environmental services provided by the newly planted trees.

What's Next?

As of May 24, 2011, the replanting program has planted nearly 6,000 trees and has found homes for over 9,000 trees for the spring and fall 2011 plantings. It will be some years before the streets of Worcester are lined with large trees again, but the diversity of trees that are being planted today will help buffer the city against future pests. Strategic placement of trees now can also help eliminate later conflicts with infrastructure such as power lines. With the many partners involved, and support at the state and federal level, Worcester and the rest of the regulated area is poised for an exciting recovery.

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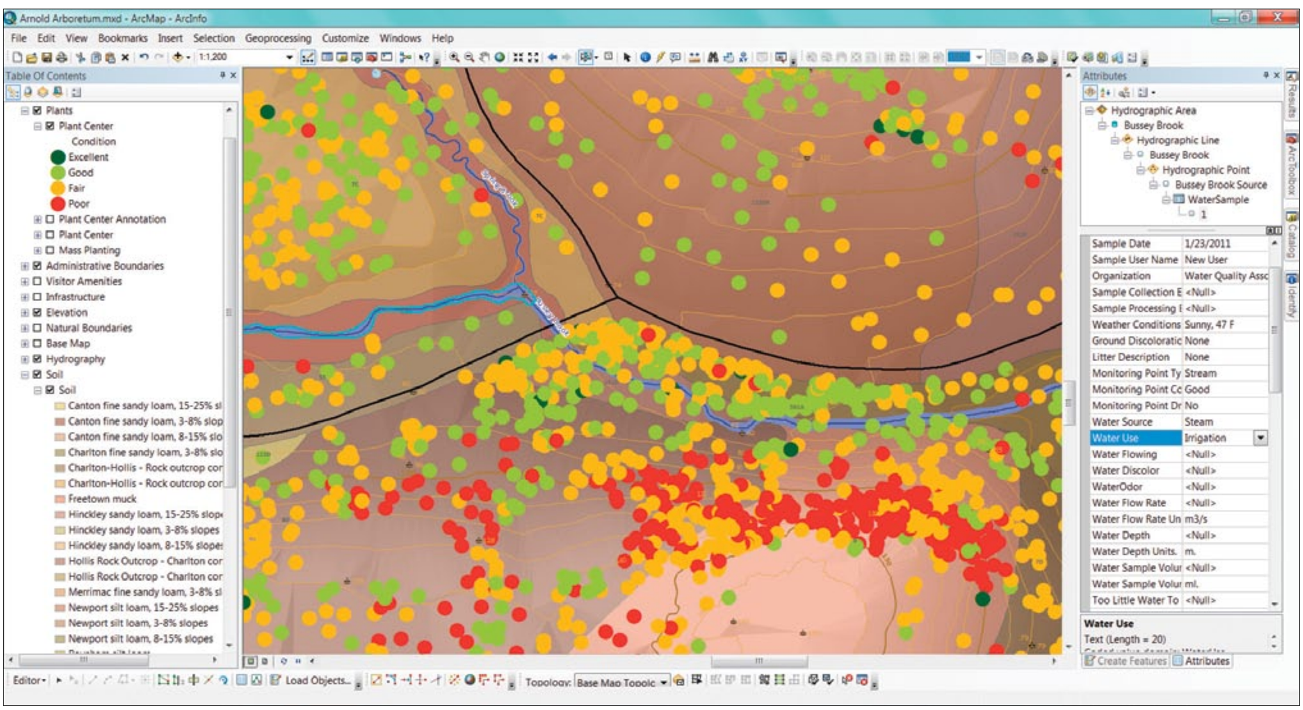
Mollie Freilicher is a Forester with the Massachusetts Department of Conservation and Recreation.

Geographic Information Systems for the Plant Sciences

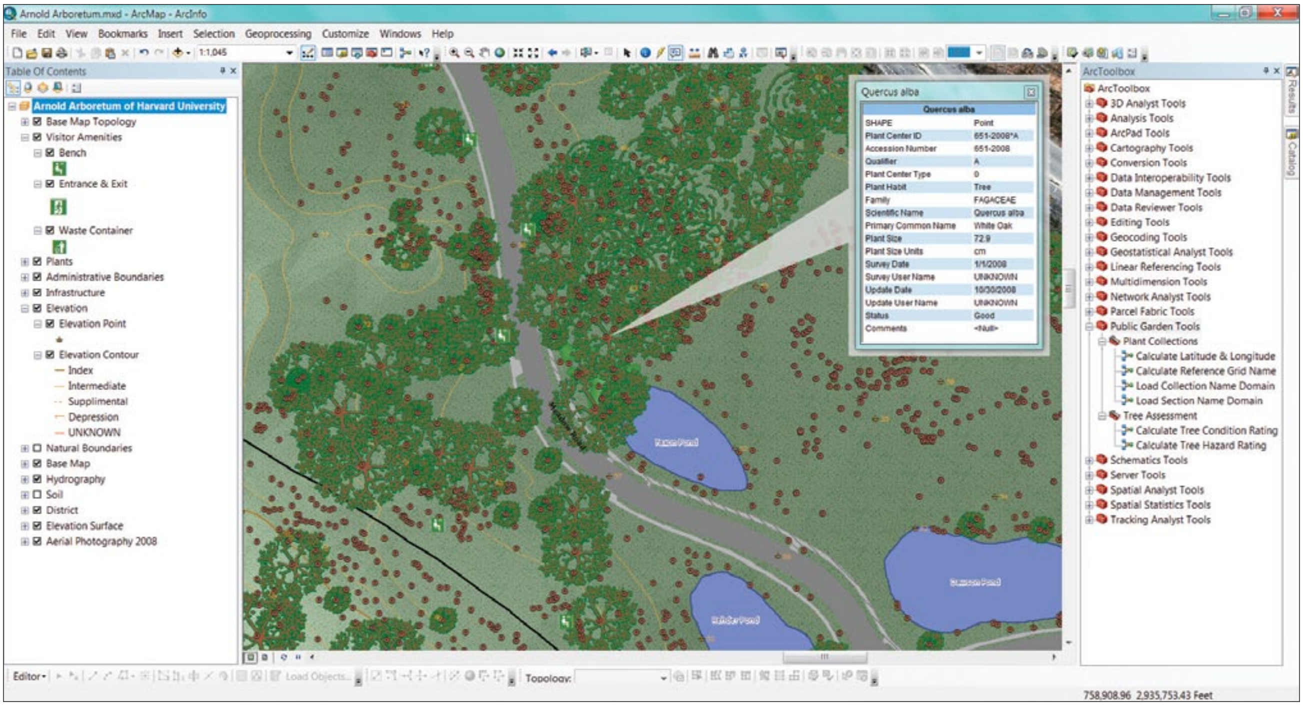
Brian J. Morgan

The disciplines of the plant sciences and geography have been intertwined as far back as circa 300 BCE when the Greek scholar Theophrastus, frequently referred to as the "Father of Botany," described the habitat and geographical distribution of plants in his first work on the subject titled *Enquiry into Plants (Historia Plantarum).* It wasn't until the sixteenth century and the establishment of the world's first botanical garden in Padua, Italy, that the leading icon of modern geography, the map, found its permanent place in the plant sciences by documenting the locations of woody plants in the garden for identification purposes. Today, location—the unifying theme of geography—has taken on an even more important role in the plant sciences where it is considered an essential attribute to record, and variable to consider, for the study of plants in fields ranging from agriculture to ecology.

In the digital age that we live in, the cataloging of plants and the analysis of the influence that location plays on the growth and distribution of them is increasingly performed using geographic information systems (GIS). GIS is commonly defined as a system of personnel, computer hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS merges the visual aspects of a map with the analytical power of a database, and allows plant scientists to view, question, understand, interpret, and visualize data in many ways that reveal relationships, patterns, and



Analysis of plant condition at the Arnold Arboretum reveals a cluster of plants in poor condition (indicated by red dots), in this case mostly eastern hemlocks (*Tsuga canadensis*) damaged by hemlock wooly adelgids.



GIS is used to explore plant collections in public gardens. By linking maps with the collections database, details about accessions such as this white oak (*Quercus alba*) are readily available.

trends in the form of maps, globes, reports, and charts. In our rapidly changing world, GIS gives scientists the power to quickly understand and formulate solutions to the problems presented by our most complex issues such as population growth, resource consumption, and climate change.

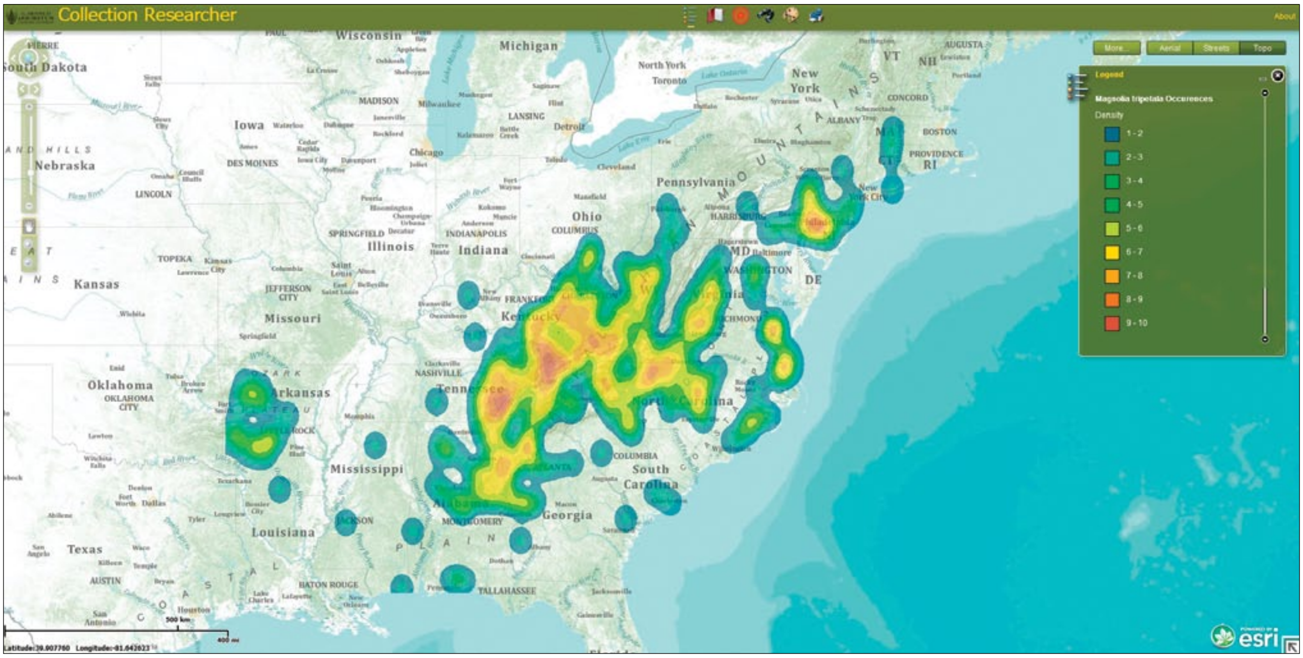
COMPONENTS OF A GIS

Personnel and Equipment

The foundation of a powerful GIS is built with the personnel required to develop and manage the system. GIS managers and analysts usually have a strong background in the principles of cartography and database management systems, and a number of graduate and certification programs have appeared in the last decade to support this education. Fortunately, recent advances in simple desktop GIS software like Esri ArcGIS Explorer for the visualization and analysis of any geographic data, and in web-based solutions like Google Maps, have made the use of GIS technology accessible to all.

With expert personnel in place, the next item needed for a geographic information system is the computer software used to capture, manage, analyze, and display spatial data. Desktop GIS software packages like Esri ArcGIS Desktop or Quantum GIS are most commonly used to perform the majority of GIS functions, but server-based systems like Map Server and Esri ArcGIS Server are increasingly being employed to share data, maps, and even analysis capabilities with users through their web browsers without the need for training or special software. These server systems even allow for the collection and use of GIS data and maps on mobile devices like smartphones and tablets that contain location sensors such as a global positioning system (GPS) receiver.

The computer hardware used for a desktop GIS is largely dependent on the requirements of the software selected, the amount and intricacy of the data to be analyzed, and the complexity of the analyses to be performed. While a standard desktop or laptop computer can be used for most systems, workstation-class desktop computers with fast processors, ample memory and storage, and high-performance graphics are most common. Server-based systems that allow multiple users to work with GIS data stored in a



A prototype web application allows users to visualize occurrences of plants in their native environments with data from the Global Biodiversity Information Facility (GBIF). This map shows the native occurrence of umbrella magnolia (*Magnolia tripetala*), a species noted for its large leaves that can reach nearly two feet long.

database management system like Postgre SQL or Microsoft SQL Server typically require the addition of a server-class computer capable of hosting the database and serving data over the local network and internet.

Spatial Data

Perhaps the most important component of a GIS is the data it contains. A large percentage of research and organizational data that is collected has a spatial component and is thus suitable for use with a GIS. This means that this data can be referenced to a location and visualized in the form of a map or globe and then analyzed to reveal relationships, patterns, and trends.

Geographic data is most easily discussed in terms of the themes that it represents, such as topography, vegetation, soils, precipitation, etc. This thematic data can be compared by overlaying layers in GIS software. This quickly allows spatial relationships between the layers to be discovered, such as the correlations between precipitation, elevation, and vegetation types.

Each thematic layer can be made up of one or more feature classes that are stored as separate files or tables in a spatial database. Feature classes are traditionally differentiated by the type of geometry used to represent real world features. For example, spot elevation measurements would be represented by points, contours of equal elevation would be represented by lines, flat water bodies like lakes would be represented by polygons, and a continuous elevation surface created from these features would be represented by a raster, or digital image, where each pixel represents the elevation value at that location.

In addition to its type of geometry, a feature class can be defined by the attributes associated with it. For example, the location of a particular plant that is represented as a point might have the name of the plant, the relative condition of the plant, and the value of the diameter at breast height (DBH) measurement stored in the file or table along with the geometry of the point itself. This combination of a map with a database allows for easy visualization of the data in GIS software, where the points representing plants can be labeled with their names, assigned different colors depending on their condition, and scaled according to their DBH measurements.

If a GIS is going to be implemented across a particular institution for long-term use, such as a conservation organization for biodiversity assessment, or a botanical garden for plant collection curation, it is common to design or employ an existing data model. A data model can be thought of as a database design or template that carefully considers how real-world features are represented as geometry in feature classes, the attributes appropriate for each feature, and any known relationships that exist between individual features or entire feature classes. In the plant sciences, user community designed data models for Esri ArcGIS exist for biodiversity assessment, forestry, and public gardens. These models can be downloaded for free and allow scientists to get started with their GIS projects quickly, without the need to design their own models. Data models like the one developed by the Alliance for Public Gardens GIS (ArcGIS Public Garden Data Model) additionally provide standardization across multiple organizations, thus simplifying the exchange of critical biodiversity data.

Whether using an existing data model or designing a new GIS from the beginning, one of the first things to consider is the availability of the data required for the project. A common starting point is to collect as much existing data as is readily available through internet data repositories like the United States Geological Survey Earth Explorer or local government spatial data clearinghouses. One of the primary sources of this data is from a technique called remote sensing which is formally defined as the collection of information about an object without making contact with it. [Ed. note: See next article for more on the use of remote sensing.] As it relates to spatial data, remote sensing usually refers to data captured from aircraft or spacecraft, and typically comes in the form of aerial photography, multi-spectral images that measure non-visible forms of electromagnetic radiation, or even LIDAR height data that is

COURTESY OF MIA INGOLIA, UC DAVIS ARBORETUM

Collecting GPS data at the UC Davis Arboretum.

Open Source vs. Commercial Software

There is much debate within the GIS developer and user community regarding the choice of commercial software versus open source software. Commercial products like those offered by Esri and MapInfo are quite expensive to purchase and typically require annual maintenance fees for support and upgrades, but offer well-designed user interfaces and sophisticated analysis tools. Conversely, open source solutions such as those that are part of the Open Source Geospatial Foundation (OSGeo) are free to use, but are more difficult to operate and get support for. Developers and scientists within academia generally tend to favor the use of open source software for GIS applications and research, while private companies and governments usually use commercial products. Ultimately, the choice is a tradeoff between cost and ease of use, but the same functionality is available from either option.

collected with a laser. Remotely sensed imagery frequently serves as a base map or background that other data—location of roads, vegetation types, etc.—can be extracted from using the techniques of supervised classification or heads-up digitizing. When this data is not sufficient for identifying features such as the location and species of plants, it is customary to collect additional data in the field by using GPS or traditional surveying techniques.

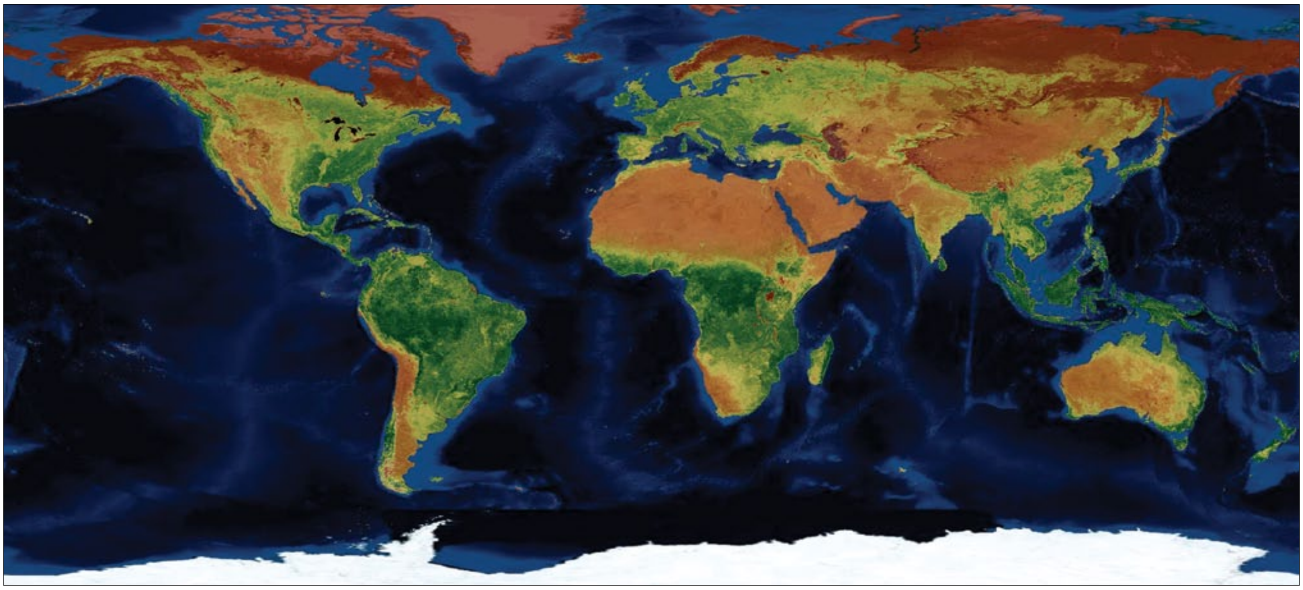
Spatial Analysis and Information Products

Once the necessary geographic and attribute data are collected for a project, the next step is to harness the true power of GIS to analyze this information in an effort to understand, question, interpret, and visualize it to reveal relationships, patterns, and trends. One common type of analysis is to investigate quantities. Plant scientists may be interested in analyzing the quantity of a particular species or group of species in a given area. Most desktop GIS software packages provide a suite of tools for working with this type of information in the form of densities, clusters, and distributions. Another common analysis is to look at what is nearby. If a cluster analysis shows a group of sensitive trees in decline, then buffering, flow analysis, and spatial statistics can be used to attempt to identify a cause by looking at topography, geology, soils, hydrology, and other related data. Many of these analysis capabilities are built into most desktop GIS software packages in the form of geoprocessing tools. These tools can be used individually or grouped together into an analysis workflow called a model. This kind of model typically has a set of adjustable parameters that influence the processing of the input data to produce a meaningful result.

Once the phase of spatial analysis is completed and a relationship, pattern, or trend has been revealed or confirmed, the final step is to summarize the results of the analysis as an information product that can be used to make decisions and take informed action. Most desktop GIS software packages have the capacity to produce a variety of information products in the form of tables, charts, reports, maps, or a combination thereof. The plant scientists investigating the previously mentioned cluster of declining trees may have determined that increased earthquake activity on a nearby fault resulted in the release of sulfuric acid into a nearby stream, thus causing their decline. To make a case for proposed mitigation, the scientists might present their findings in the form of a map showing the locations of the geologic, hydrologic, and plant features of concern along with a chart showing the increased sulfuric acid concentrations over time, and perhaps a second map detailing their proposed plan. If the results of this study need to be conveyed to a wider audience such as stakeholders or the general public, a server-based solution might be employed to create another type of information product, a web browser application that allows users to explore and interact with the scientists' data themselves. This is just one hypothetical example of how GIS can be used in the plant

COURTESY REBECCA SUCHER, MISSOURI BOTANICAL GARDEN

Mapping a plant collection at the Missouri Botanical Garden in St. Louis, Missouri.



Global greenness (vegetation) can be evaluated with the Normalized Difference Vegetation Index (NDVI) from remote sensing data gathered by satellites.

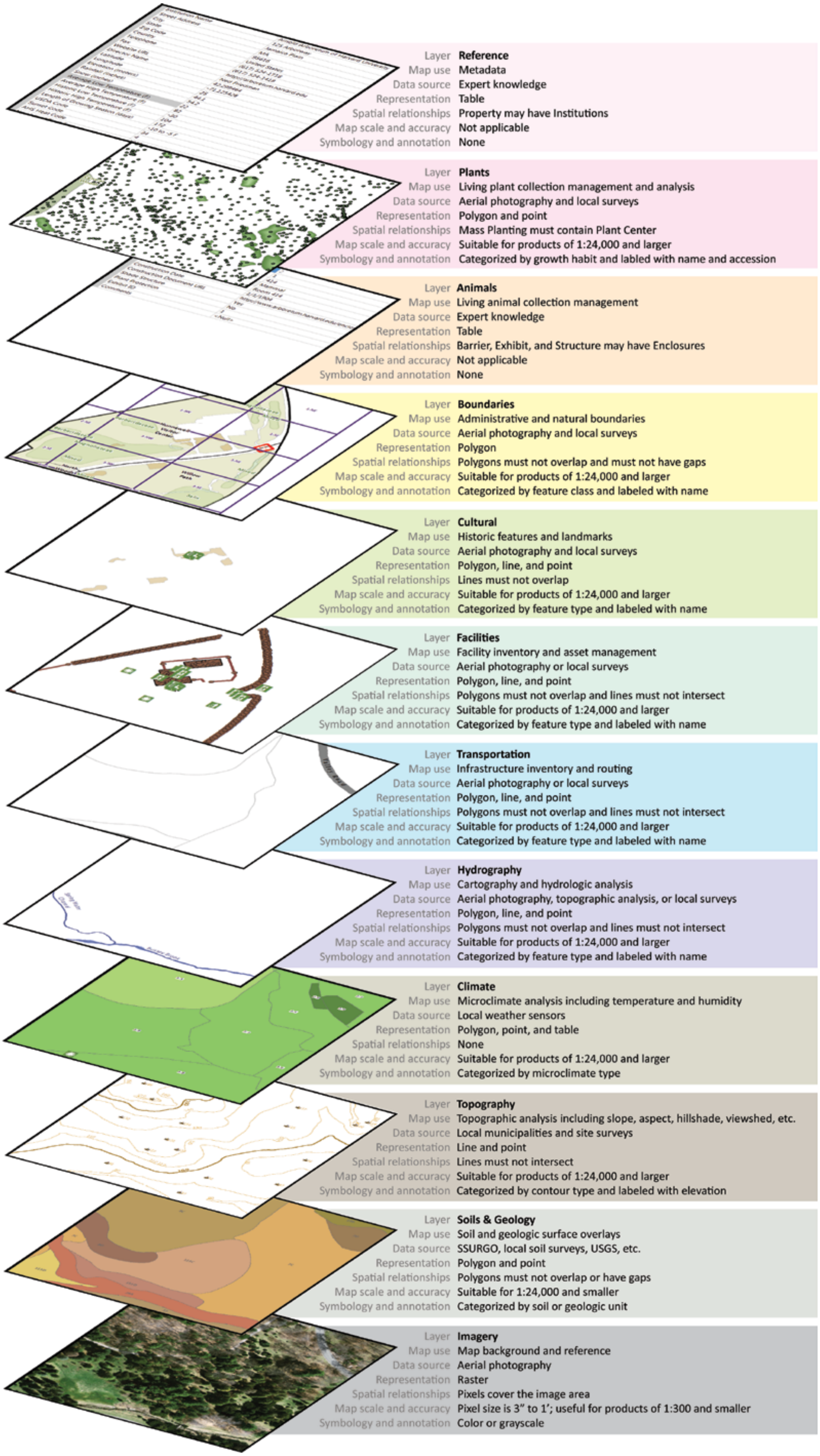
sciences. The next section describes how it is being employed in real-world projects for both research and management.

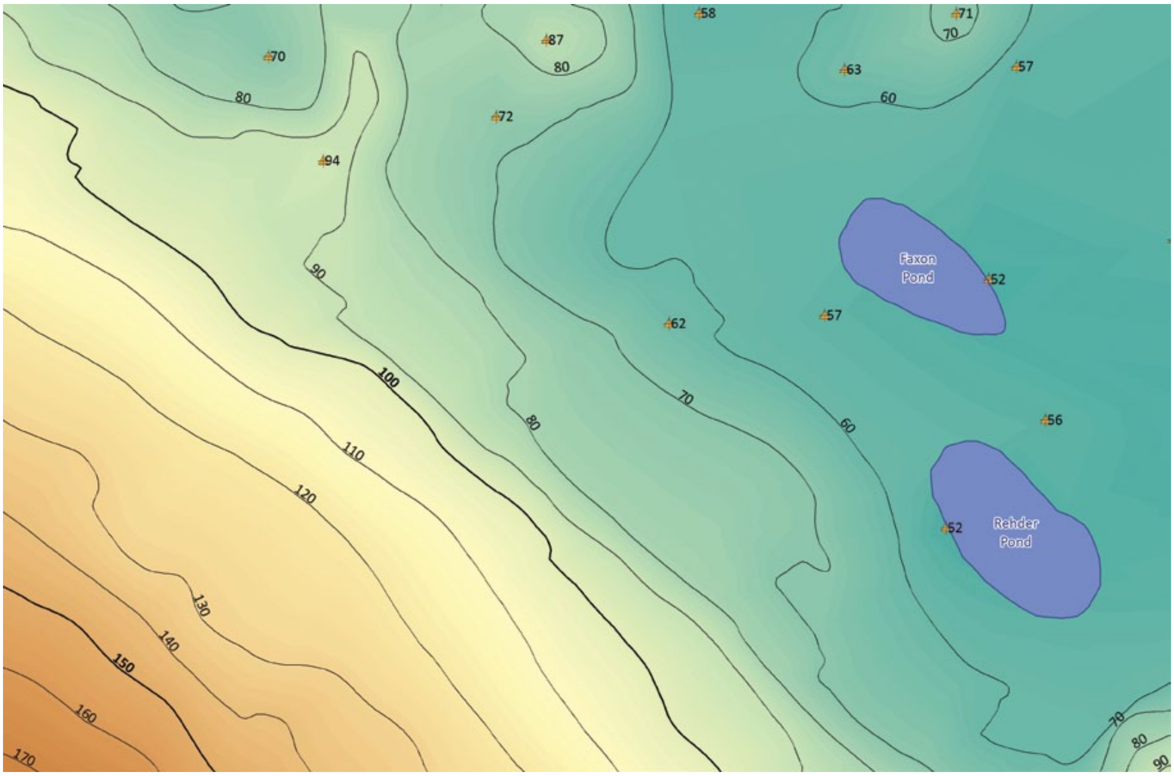
APPLICATIONS OF GIS

Our ever increasing need for land and resources combined with the threat of climate change has pushed the assessment of biodiversity to the top of the list of plant science research priorities. The scientific literature is rich with articles on the subject, ranging from studies of parks and reserves to the entire planet. GIS is often cited as the primary tool used to perform many of these studies, which frequently employ species occurrence data from informatics sites like the Global Biodiversity Information Facility (GBIF) and remotely sensed data from satellites like Landsat 7 TM to determine the relative species richness of a particular area. In one study of African vascular plant diversity, the investigators performed a multivariate analysis to determine the relationship between the number of species in well-known areas and the associated environmental conditions like topography, temperature, precipitation, and evapotranspiration. This relationship was then used to interpolate the species richness in lesser-known areas to produce a vascular plant diversity map for the entire continent (Mutke et al. 2001).

Once the biodiversity of an area has been assessed, the spatial data generated from the assessment can be used to help prioritize which parcels of land should be designated as conservation areas. Since the study of land and the process of delineating boundaries are inherently spatial in nature, GIS is cited as the overwhelming choice of tool for the task. In addition to biodiversity data similar to that produced in the previous study, conservation planning activities usually include topography, precipitation, soil, geology, and land use data. In a forest conservation study in Malaysia the investigators used a decision making approach that assigns weighted values to possible alternatives in an effort to prioritize areas for conservation. This study considered species and ecosystem diversity, the soil and water conservation functions of plants, and potential threats to the forest, and through a process called map algebra, hot spots for conservation were determined and used to delineate potential new protection areas (Phua and Minowa 2005).

GIS can also be an invaluable tool when planning a collecting expedition. Traditional approaches to expedition planning have favored areas that were considered interesting or easily accessible, and tended to focus on species that were easily studied. GIS allows for the unbiased


Layer Reference
Map use Metadata
Data source Expert knowledge
Representation Table
Spatial relationships Property may have Institutions
Map scale and accuracy Not applicable
Symbology and annotation None
Layer Plants
Map use Living plant collection management and analysis
Data source Aerial photography and local surveys
Representation Polygon and point
Spatial relationships Mass Planting must contain Plant Center
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by growth habit and labled with name and accession
Layer Animals
Map use Living animal collection management
Data source Expert knowledge
Representation Table
Spatial relationships Barrier, Exhibit, and Structure may have Enclosures
Map scale and accuracy Not applicable
Symbology and annotation None
Layer Boundaries
Map use Administrative and natural boundaries
Data source Aerial photography and local surveys
Representation Polygon
Spatial relationships Polygons must not overlap and must not have gaps
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by feature class and labeled with name
Layer Cultural
Map use Historic features and landmarks
Data source Aerial photography and local surveys
Representation Polygon, line, and point
Spatial relationships Lines must not overlap
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by feature type and labeled with name
Layer Facilities
Map use Facility inventory and asset management
Data source Aerial photography or local surveys
Representation Polygon, line, and point
Spatial relationships Polygons must not overlap and lines must not intersect
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by feature type and labeled with name
Layer Transportation
Map use Infrastructure inventory and routing
Data source Aerial photography or local surveys
Representation Polygon, line, and point
Spatial relationships Polygons must not overlap and lines must not intersect
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by feature type and labeled with name
Layer Hydrography
Map use Cartography and hydrologic analysis
Data source Aerial photography, topographic analysis, or local surveys
Representation Polygon, line, and point
Spatial relationships Polygons must not overlap and lines must not intersect
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by feature type and labeled with name
Layer Climate
Map use Microclimate analysis including temperature and humidity
Data source Local weather sensors
Representation Polygon, point, and table
Spatial relationships None
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by microclimate type
Layer Topography
Map use Topographic analysis including slope, aspect, hillshade, viewshed, etc.
Data source Local municipalities and site surveys
Representation Line and point
Spatial relationships Lines must not intersect
Map scale and accuracy Suitable for products of 1:24,000 and larger
Symbology and annotation Categorized by contour type and labeled with elevation
Layer Soils & Geology
Map use Soil and geologic surface overlays
Data source SSURGO, local soil surveys, USGS, etc.
Representation Polygon and point
Spatial relationships Polygons must not overlap or have gaps
Map scale and accuracy Suitable for 1:24,000 and smaller
Symbology and annotation Categorized by soil or geologic unit
Layer Imagery
Map use Map background and reference
Data source Aerial photography
Representation Raster
Spatial relationships Pixels cover the image area
Map scale and accuracy Pixel size is 3" to 1'; useful for products of 1:300 and smaller
Symbology and annotation Color or grayscale

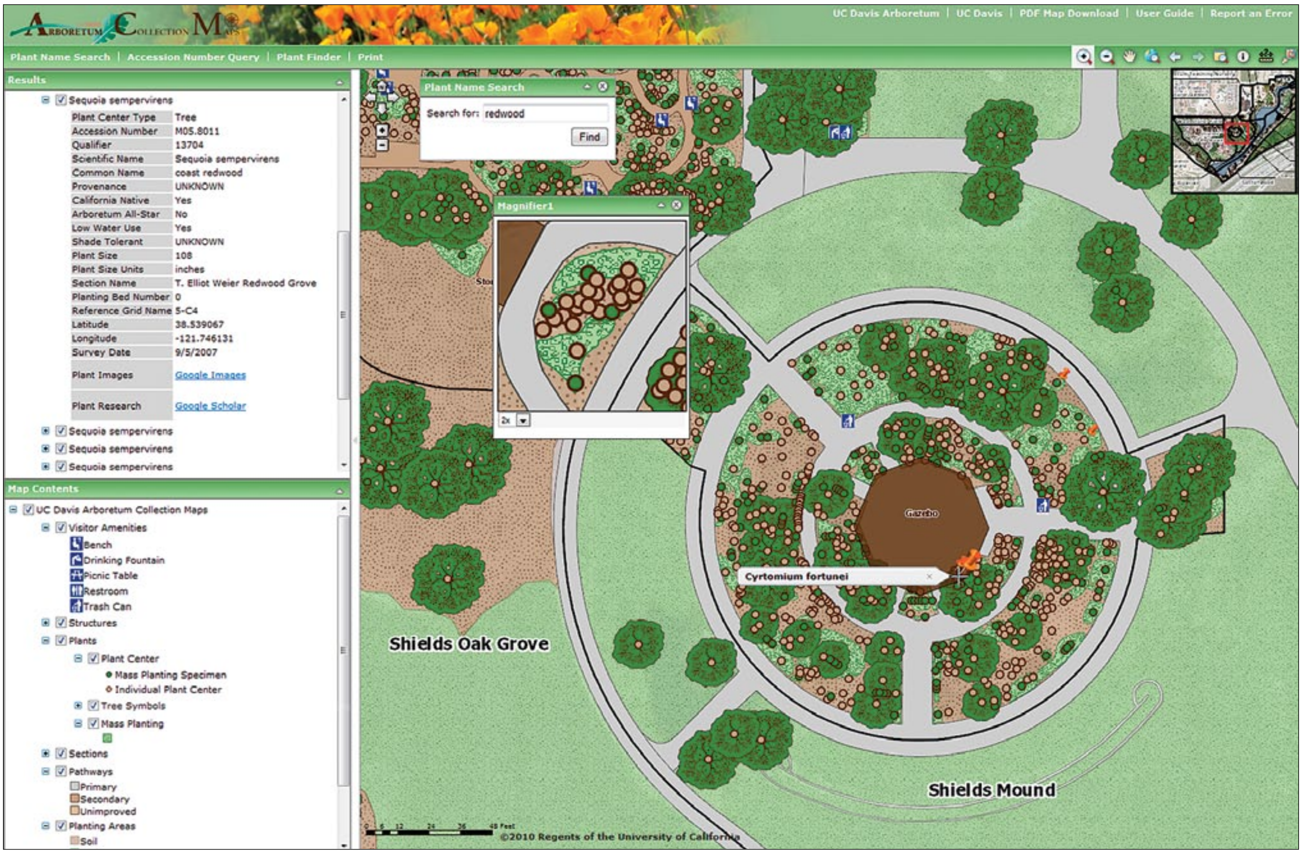


GIS data can be represented as points, lines, polygons, and rasters. Here spot elevations are shown as points, contours are shown as lines, ponds are shown as polygons, and an elevation surface is shown as a raster in part of the Arnold Arboretum.

sampling of an area that not only maximizes heterogeneity, but can also assure that the largest gaps in the record of biodiversity are filled with the least amount of effort and resources. GIS-based expedition planning typically utilizes existing biodiversity data along with topography, geology, vegetation, temperature, and precipitation data to determine areas that have the greatest potential to provide the maximum amount of new information and specimens. In a survey gap analysis study in Guyana the investigators used museum and herbaria specimen data to locate geographical gaps in the existing data in an effort to determine candidate survey sites for each taxonomic group of interest. These candidate sites were then compared with weighted abiotic variables to determine a final set of collecting sites that had the greatest chance of producing new information and specimens for each taxonomic group (Funk et al. 2005).

Once plant specimens have been collected and cultivated in a botanical garden or arboretum, GIS is commonly used to curate the collection and to help make management decisions throughout the entire lifetime of the plant. GIS is commonly used for creating collection maps and planting plans, identifying problems and threats, planning mitigation, and performing research. In addition to data about the living collection, a typical garden GIS employs data on topography, soils, hydrology, land use, facilities, transportation and more. In a tree conservation study at the UC Davis (University of California, Davis) Arboretum the investigators used data on the location, species, size, and condition of each specimen in conjunction with data on site characteristics and conflicting urban infrastructure to determine a condition rating and a hazard rating for each tree in the collection. These ratings were then used to identify areas of concern and to produce prioritized mitiga-

Facing page: **Thematic layers in the ArcGIS Public Garden Data Model allow comparisons and correlations of databases from soils and topography to plants and animals.**



UC Davis Arboretum Collection Mapper allows users with no GIS experience to explore plant collections.

tion plans that considered the safety of visitors and impact on the rest of the living collection (Ingolia 2010).

THE FUTURE OF GIS

Studies such as these would be difficult, if not impossible, to complete without the use of a GIS. Not only are the results of these studies valuable to the scientific community, but the data generated during the process can be shared and employed by researchers in future efforts. As our world continues to evolve at a quickening pace, and threats to plants in their native environments rise, our ability to quickly understand and formulate solutions to these complex issues is essential to plant conservation. Geographic information systems provide us with a platform to accomplish this and much more, and as our society becomes increasingly location aware, this technology is likely to become one that we question how we ever lived without it. Do you know where your plants are?

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Remote Sensing as a Botanic Garden Tool

Ericka Witcher and Patrick Griffith

A 2008 aerial photo of Montgomery Botanical Center property in south Florida.

Remote sensing is a tool already in use for plant exploration, ecology, forestry, habitat restoration, and other related fields. It also has great potential in botanic gardens for botany, horticultural science, and management purposes. At Montgomery Botanical Center, located in Coral Gables, Florida, we were able to improve our assessment of the property with the addition of new software that provided the capability for deeper evaluation of the collections and natural resources using remote sensing imagery and data. By adding LIDAR (Light Detection And Ranging) imagery to maps and employing techniques normally used at larger regional scales, new information was discovered about the garden and its collections.

Garden maps serve multiple purposes. Their primary use is as a location catalog—what a garden has and where it is. People who use the garden, whether staff or visitors, will want to know where certain features are at some point. The information displayed in this kind of map can reflect the vastly different purposes of, say, a researcher examining different subspecies of *Coccothrinax miraguama* (miraguama palm), an irrigation technician repairing a break, or a visitor looking for the restroom, but all three of their garden maps would need to show what things are and where they are located. On the other hand, maps can also be used for more dynamic purposes in the garden. New areas of horticultural and scientific interest can be illuminated through the addition of a spatial or geographic component—where things are in relation to something else. Spatial relationships in a botanical garden, for example, can examine how close vulnerable plants are to open spaces or high-use visitor areas, how tree canopies change over time, or the density of plantings. Expanding beyond the property, considerations regarding latitude and regional topography can be taken into account. Integrating a garden map into a Geographic Information System (GIS) is a way to keep and readily analyze a lot of data about a lot of different things in a garden.

A Garden for Conservation and Research

Montgomery Botanical Center (MBC) is a non-profit research institution. With 120 acres in a sub-tropical latitude, we are able to specialize in palm and cycad taxa that would have difficulty growing elsewhere in the United States (Calonje et al. 2009, Noblick et al. 2008). MBC's living plant collections are well-documented and population-based in order to reflect the genetic diversity found in the wild, and they have great research and plant conservation value. People of all backgrounds—from students to hobbyists to commercial growers—can observe and examine unusual, rare, or endangered specimens they might not have the opportunity to see in the habitats of origin, or in side-by-side comparative collections that would not occur in the wild (Husby et al. 2010). Because of the exotic

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Shade and soil needs are affected by what is overhead and underfoot: for example, the dappled shade and natural mulch provided by this *Ficus racemosa* counteracts the stress of alkaline soil on the *Chamaedorea stolonifera* now thriving at its base. Similar conditions must be found for future plantings.

Definitions

Remote sensing data: ***Quantifiable information collected from a distance about something, such as measured elevations or the hue of vegetation, usually referring to aerial or satellite signal collectors.***

Remote sensing imagery: ***The composite pictures created from the collected data.***

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Vegetative and geologic characteristics, like canopy and elevation changes seen here along the Palm Walk, are quantifiable with LIDAR-integrated maps.

origins or sensitive nature of many plants in our collections, we must work to create and maintain an environment that provides for their individual needs for life and growth. To that end, we are continually looking for new ways to assess the garden property and analyze both its biological and geological resources.

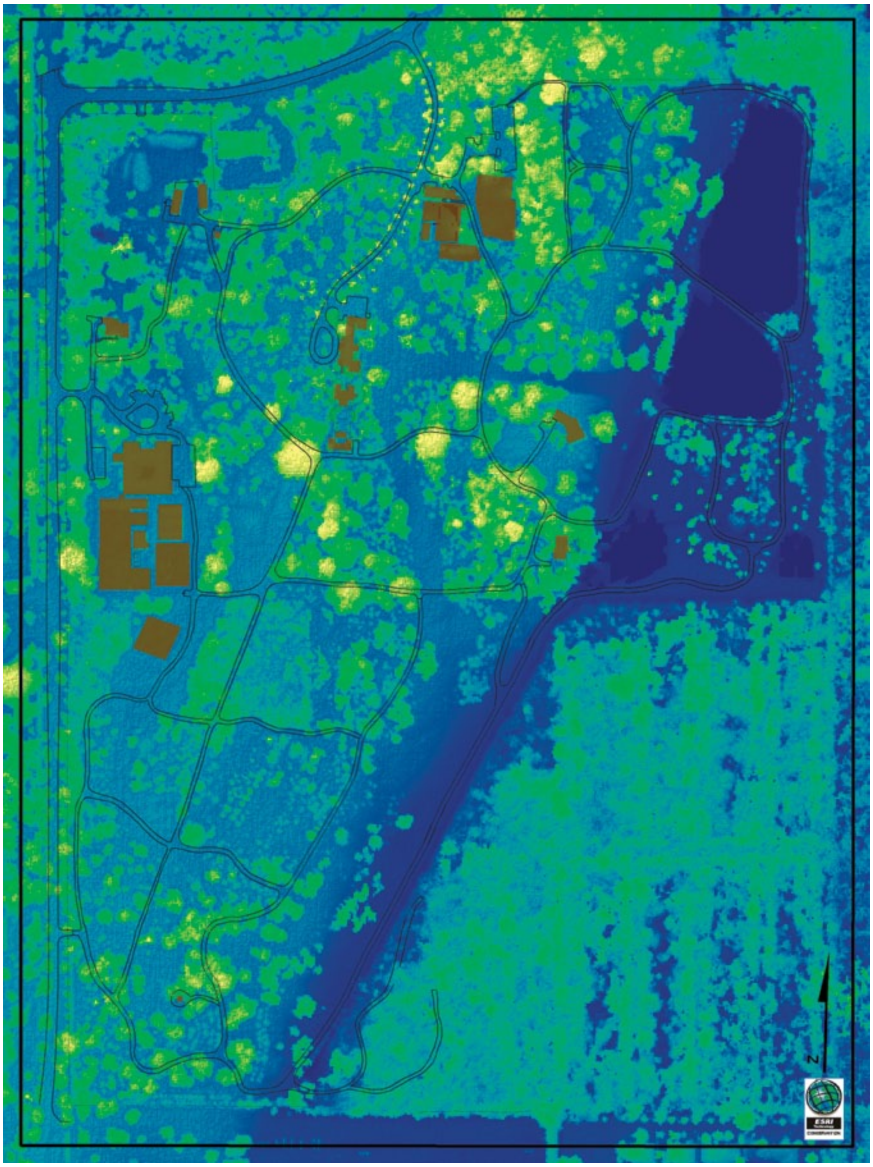
Legacy Imagery

For several years we had utilized aerial photographs to examine tree canopy and other features at MBC that were difficult to thoroughly evaluate from ground level. Orthophotographs (planimetrically-corrected aerial photographs) and uncorrected aerial photos are frequently used in many different industries, including botanic gardens, for many disparate purposes, and are readily available through a variety of sources (e.g., the USGS website http://www.usgs.gov/pubprod/, or state or county websites). These photos provided a good general sense of how areas were developing, but we experienced a fair amount of difficulty integrating them with our AutoCAD (a computer-aided-design software program)-based maps, so their utility was somewhat limited. We wanted a way to view the photos and the maps at the same time as well as use other types of imagery, then be able to perform spatial analysis.

New Systems Add Capability

A software grant for botanical gardens and zoological parks provided an all-in-one solution. Two MBC staff members had prior experience with the software, and with the help of an additional intern, by late 2009 we had completely converted the old maps and their CAD layers to a GIS (geographic information system). The local coordinate system was replaced with geographic latitude and longitude so the converted CAD layers would relate to Earth's surface. MBC was then able to add one more tool to their garden shed: remote sensing data and imagery.

The ability to use remote sensing data in conjunction with map files opened up entirely new ways of visualizing the garden property. Tree canopies were accurately identified by species by overlaying the mapped plant points onto the orthophotos. Map files of road edges and lake boundaries from 10 years before were adjusted to align with their current locations. Instead of looking at information imposed on a representation of the property, the information was examined in view of the property as a whole in the real world.

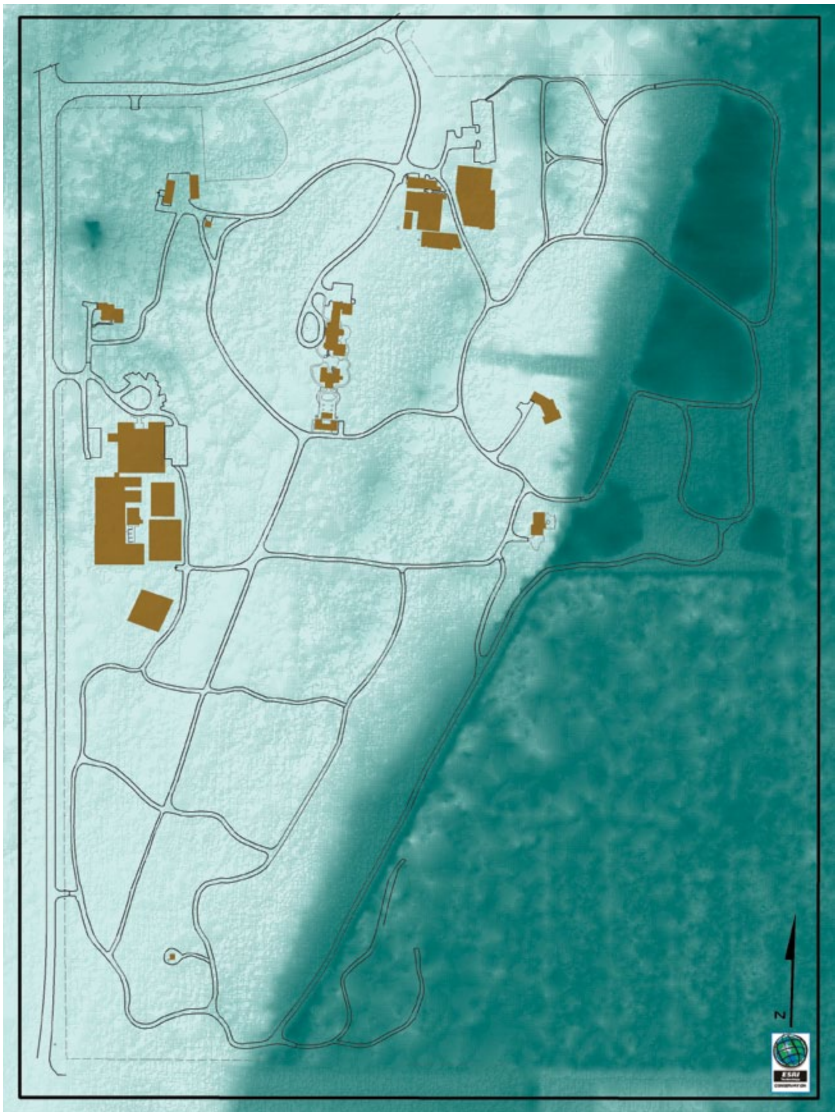


BY ERICKA WITCHER FOR MONTGOMERY BOTANICAL CENTER

First-Return LIDAR image of MBC property showing topmost surfaces, where bright yellow is the highest elevation and deep blue is the lowest.

MBC also lacked an accurate elevation map. The landscape in South Florida is flat enough that a gain of even one foot (0.3 meters) is a substantial difference in regard to the water table and underlying soil, which are of great importance to plants (Kitaya et al. 2002), but such a subtle variation is often difficult to detect while performing fieldwork. To remedy this, in 2010 we made our own contour map with the GIS software, using a bare-earth LIDAR image of the property. LIDAR imaging uses measurement of the time it takes a laser pulse to be transmitted from and reflected back to an overhead receiver (like an airplane or satellite) to generate a visual dataset. In other words, while aerial photos create a two-dimensional horizontal image, LIDAR adds a third dimension: elevation. LIDAR also is increasingly freely available from local, state, and federal government agency websites (e.g., the USGS website http://lidar.cr.usgs.gov/). A bare-earth LIDAR image displays ground-level data as opposed to treetops and rooflines. With this height information added to the maps, we could concretely see geological aspects that we could only intuit before. Important inland low-lying areas as well as property high points were clearly identifiable, and the labeled contour map provided practical delineations for field work.

BY ERICKA WITCHER FOR MONTGOMERY BOTANICAL CENTER



Bare-Earth LIDAR image of MBC property showing ground level surface geology; lower (darker) areas west of the escarpment are important for planting, as they are more likely to contain sand and silt, in contrast to the surrounding alkaline limestone bedrock, or the clay marl to the east.

A first-return LIDAR image also offered a lot of utility for other vegetation-assessment projects. First-return images illuminate all the topmost surfaces of the study area; in this case, canopy height and coverage. In one project, an undeveloped section of the property filled with both an invasive exotic plant, *Schinus terebinthifolius* (Brazilian peppertree), and protected mangrove trees needed a thorough evaluation so we could determine the most efficient course of action for managing the land. Canopy height and density were examined in the LIDAR images and transects were distributed and performed accordingly. The invasive plant was not found to be as pervasive as feared, and as a result, eradication efforts were scaled down proportionally (Edelman and Griffith 2010). Using LIDAR imagery to better visualize the dense plant growth beforehand gave us a more complete picture prior to entering the area, saving time and effort.

For another project we adapted a conventional forestry analysis using first-return LIDAR images to appraise height and breadth information (Sumerling 2010) to establish potential candidates for national or state champion tree status. (Champion trees are the largest known individuals of a species based on measurements of height, trunk circumference, and canopy spread.) This was done by simply overlaying the plant layer over the image and visually identifying the tallest canopies. The plant curators also applied their in-field knowledge of the various species' usual growth habits to propose more individuals for assessment, the height and spread of which were also checked in the LIDAR map. At writing, 27 trees had been awarded state champion status by the Florida Division of Forestry, and 2 trees received national champion status from the conservation organization American Forests.

Future Development

With the successful completion of these projects, we have become more familiar with the uses of both aerial photography and LIDAR for horticultural purposes, and subsequently the

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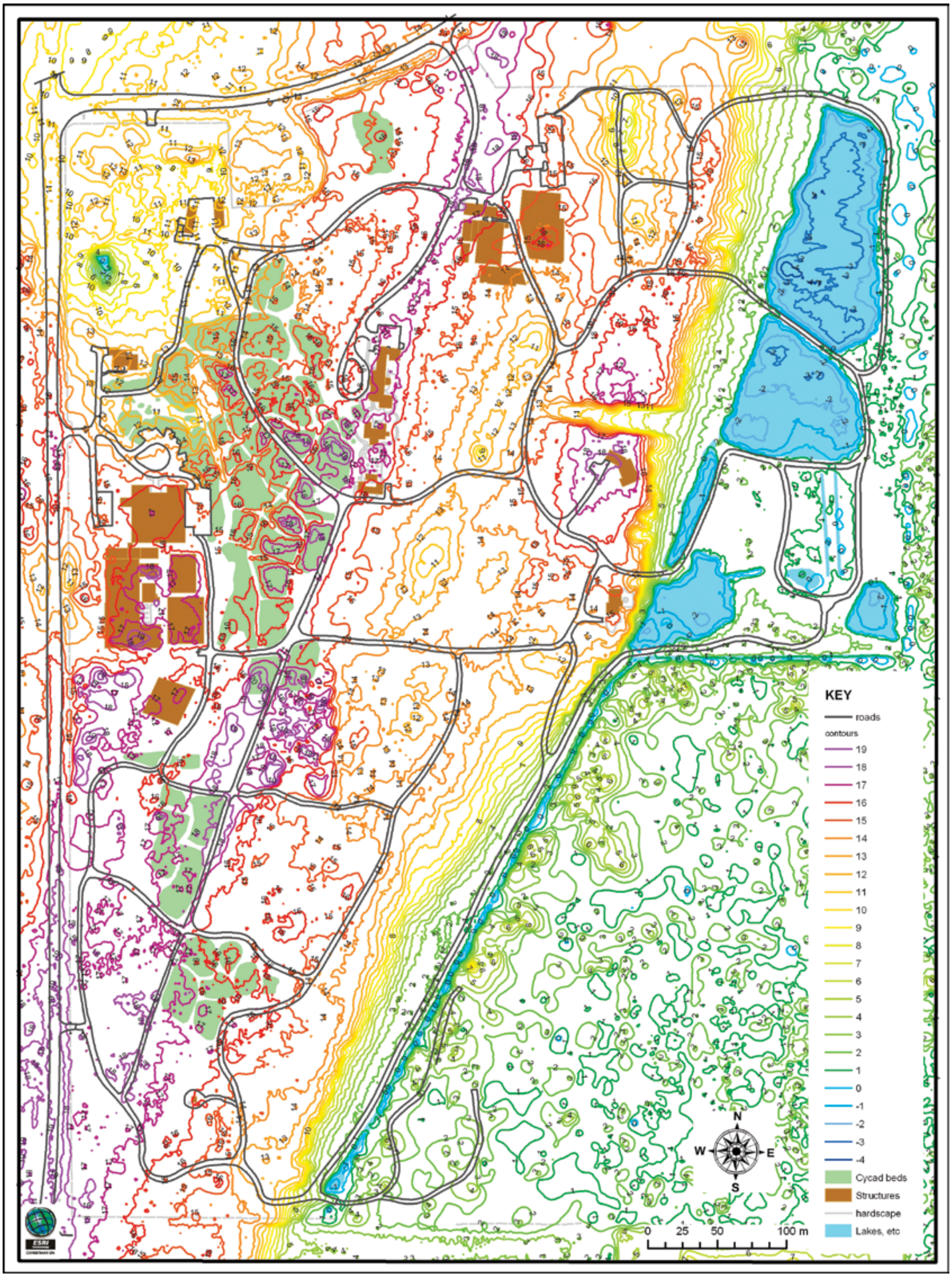
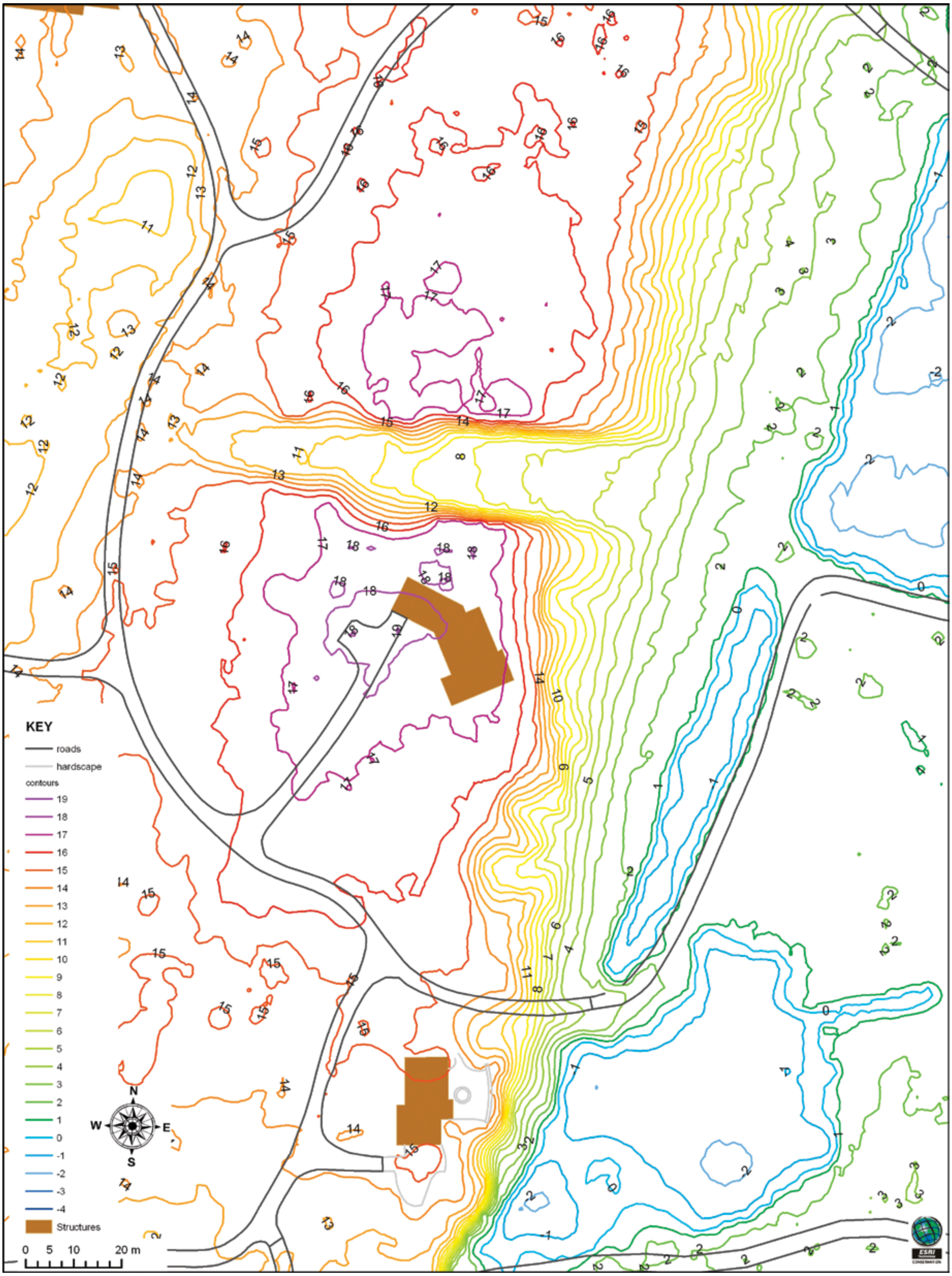


MBC staff created their own topography map with a LIDAR image and GIS software. Note the allée in the escarpment running through the northeast quadrant, seen in detail on facing page. This point on the escarpment was one of the highest points on the property until Robert Montgomery excavated the rock to create the allée in the 1940s, in order for his wife, Nell, to view the lakes from the main house (Anderson and Griffith, in press).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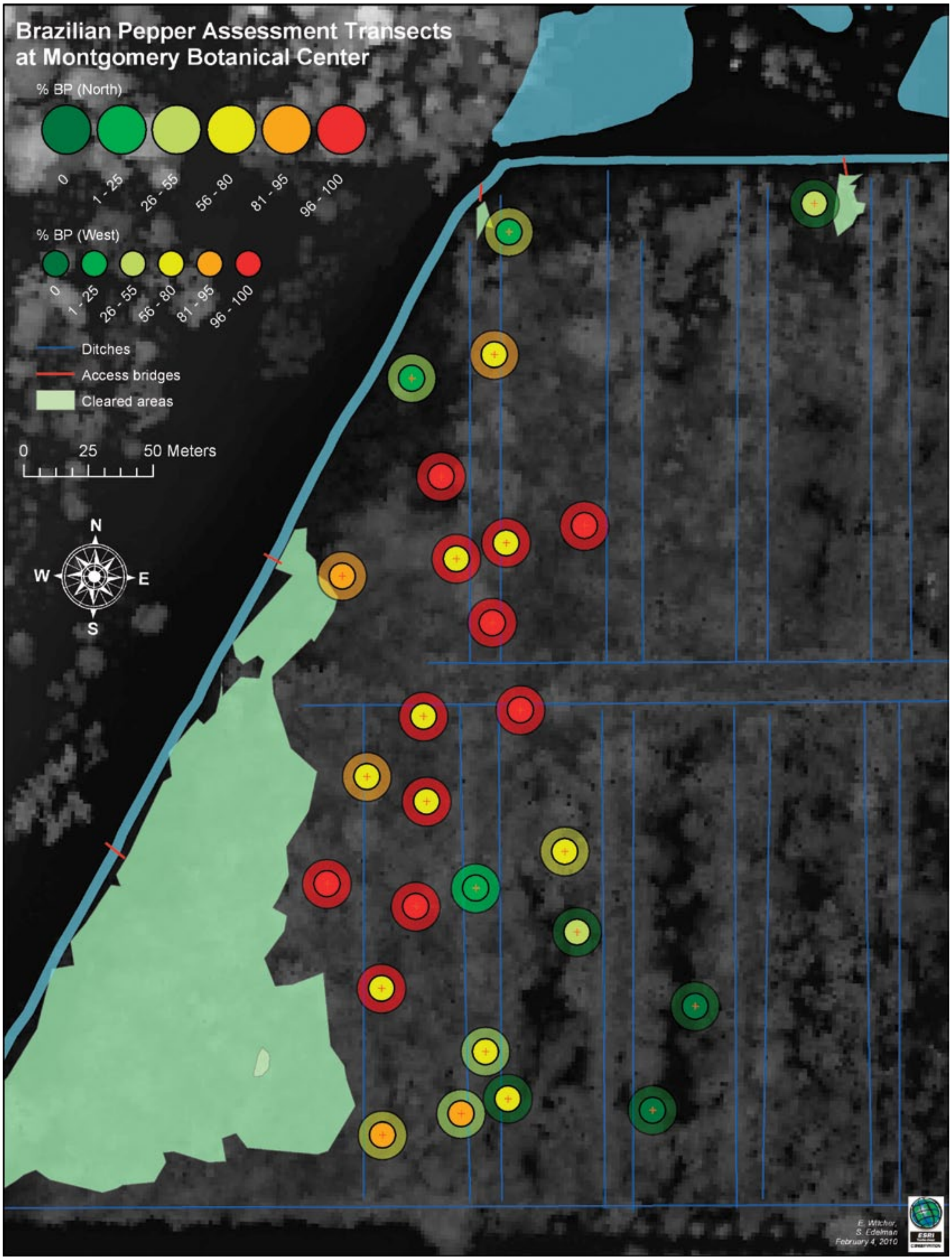

LIDAR helps make informed property management decisions at MBC. Thirty-meter transects were performed to the north and west at each point to assess approximately how much of overhead canopy consisted of invasive Brazilian pepper (BP). Large circles show percentage BP found to the north, and small circles show percentage BP to the west. Due to mangrove protection laws, greater caution must be used during removal wherever a transect was not solid red. A map of the results indicates areas of the most worthwhile effort.

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This Florida champion tree, *Pterygota alata* (Buddha coconut), has endured dozens of hurricanes, and at 89 feet tall is one of the tallest trees on our property. We first identified it as a candidate through examination of LIDAR imagery.

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LIDAR imagery provides clues to planting conditions at MBC for staff biologist, Chad Husby, looking for future plant sites near the allée.

potential applications for this kind of data. We are also exploring additional applications currently in use by other landscape-level industries that have a good deal of potential for use in botanic gardens (Perroy et al. 2010, Sumerling 2010). For example, we are now working on creating contours from a first-return LIDAR image that will provide new information about the canopy coverage and biomass density in the garden. This type of three-dimensional data can amplify current knowledge about shade structure, wind protection, and plant growth and expansion within the property and create an operational image of the "vegetative topography." Coupled with 15 years of database records tracking the growth and reproductive activity over time of our plants, we anticipate new insights to spur in-depth research. LIDAR also lends itself to three-dimensional modeling and creating fly-throughs, leading to comprehensive visual aids for online garden "explorers" and researchers, as well as garden managers looking to gain new perspectives on their collections and resources.

Meanwhile, maximizing survival rates of invaluable scientific plant collections with analysis of current collections and records, both spatial and temporal, is an ongoing objective. By employing imagery in our GIS and adapting some of the more basic and conventional uses of LIDAR for regional landscapes to the localized, relatively small-scale botanical garden, we have been able to save many hours of laborious fieldwork and gain a nuanced understanding of the property and plants under our care.

Acknowledgements:

We thank Brian Witcher and Judd Patterson of the National Park Service SFCN program for their GIS assistance and consultation, MBC GIS Intern Jonas Cinquini and MBC Intern Sara Edelman for their project assistance, the Stanley Smith Horticultural Trust for all GPS equipment funding, and the ESRI Botanical Garden/ Zoological Park Grant program for providing all GIS software.

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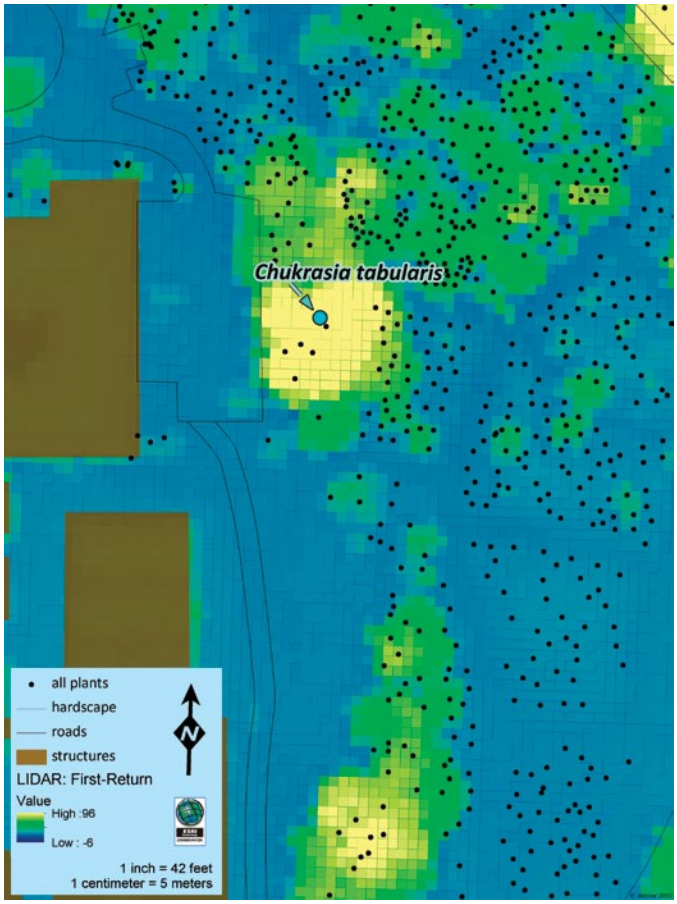

BY ERICKA WITCHER FOR MONTGOMERY BOTANICAL CENTER

Chukrasia tabularis **(Burmese almondwood) is prized for its beautiful hardwood. This specimen at MBC is the Florida state champion tree and was first identified as a candidate through examination of LIDAR imagery (right). LIDAR scale is in feet.**

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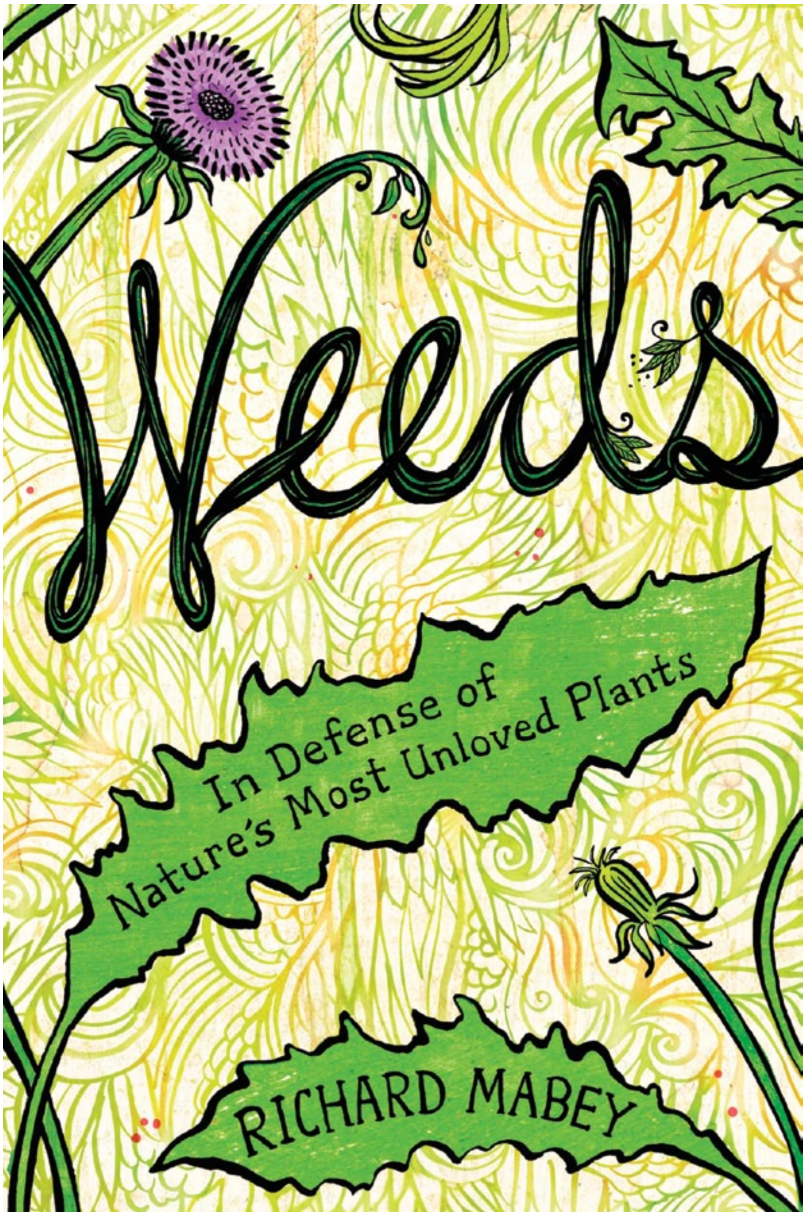
BOOK REVIEW:

Weeds: In Defense of Nature's Most Unloved Plants

Peter Del Tredici



Weeds: In Defense of Nature's Most Unloved Plants
Richard Mabey. Ecco, an imprint of HarperCollins Publishers.
324 pp. 2010
(United States publication 2011)
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In his new book *Weeds: In Defense of Nature's Most Unloved Plants,* Richard Mabey presents a refreshingly non-judgmental look at some of the most vilified plants on earth. While acknowledging the problems that some of these notorious plants can cause for both gardeners and ecosystems, he also presents their not insubstantial positive contributions in terms of recolonizing derelict land in cities, restoring war-ravaged landscapes in Europe, and, over the millennia, providing abundant food and medicine for people. In short, the author takes a balanced approach to the subject of weeds and he puts the focus where it belongs—on their intimate association with human culture going back to the dawn of agriculture itself.

As Mabey presents it, the subject of weeds is nothing less than a microcosm of human culture, an observation that he reinforces with numerous quotations from famous writers including Shakespeare, Ruskin, and Thoreau, and, of course, from the Bible. Not stopping here, he also provides a lengthy discussion of the significance of weeds in visual arts, as exemplified by a discourse on the significance of Albrecht Dürer's famous painting from 1503, *Large Piece of Turf,* which he describes as, "… not only the first portrait of a community of weeds, it is the first truly naturalistic flower-painting in Europe, and the herald of a new humanistic attitude towards nature."

A more modern example is his discussion of the science fiction classic *The Day of the Triffids* (first published as a book in 1951 and released in 1962 as a movie, now a cult favorite), which Mabey presents as a metaphor for

Great Piece of Turf **(also known as** ***Large Piece of Turf*****), 1503, by Albrecht Dürer (1471–1528). Graphische Sammlung Albertina, Vienna, Austria / The Bridgeman Art Library.**

aggressive invasive species such as giant hogweed (*Heracleum mantegazzianum*) and kudzu (*Pueraria montana*). It should also be noted that the book is up-to-date in its discussion of the modern, scientific data on weeds, discussing in detail how the increased use of herbicides over the past fifty years has influenced weeds' evolution, and how genetically modified (GM) crops are interacting with weeds to make them hardier and more difficult to eradicate. In short, Mabey masterfully weaves the disparate fibers that constitute the cultural and natural history of weeds into a colorful tapestry of a book that few nature writers can match.

Weeds: In Defense of Nature's Most Unloved Plants is not without a few flaws however, one of which (for American readers) is its exclusive use of the British common names of plants throughout the text. There is a glossary at the end which provides the Latin equivalent to the common name, but the fact that many of the plants discussed in the book have different common names in North America than they do in England leaves the inquisitive American reader who doesn't know the Latin names of plants with little choice but to turn to the internet or reference books to figure out identities. In addition, the book is overwhelmingly focused on weeds that dominate the landscapes of the British Isles and on British writing on the subject, making the book somewhat less relevant to North American audiences than it perhaps needs to be. Certainly the history and behavior of North American weeds is discussed in the book, particularly the subject of their early introduction from Europe, but their treatment is minimal compared to the space devoted to weeds in Britain. There's also a surprising absence of any mention of the extensive pioneering German literature on the subject of urban ecology, particularly that done by Herbert Sukopp and his colleagues in post-war Berlin.

Despite the British focus of *Weeds: In Defense of Nature's Most Unloved Plants,* I found it a fascinating read—which is no small accomplishment given the fact that I have a large library of well-studied weed books at home. Mabey is an engaging writer with long-standing, highly personal interest in weeds that shines through on every page. He deserves kudos for his masterful integration of the scientific and cultural aspects of weed ecology and his fluid, often poetic, use of language. Here he describes watching weeds grow at an active construction site:

NANCY ROSE

Dandelion (*Taraxacum officinale*).

> "When I look at their comings and goings, as hectic as the movements of the bulldozers, I grope for metaphors to understand their meaning. I think of ants, but they're too organized, too determinedly earth-changing, like the excavating machinery itself. Then it occurs to me that they are like a kind of immune system, organisms which move in to repair damaged tissue, in this case earth stripped of its previous vegetation."

While this book has something for everyone, I suspect that its greatest appeal will not be to down-in-the-dirt gardeners but to those of the armchair persuasion who like their weeds with a touch of literature, humor, and taste.

Peter Del Tredici is a Senior Research Scientist at the Arnold Arboretum.

A Venerable Hybrid Oak: *Quercus* x *sargentii*

Michael S. Dosmann

Scores of plant taxa—species, infraspecific variants, and hybrids—commemorate Charles Sprague Sargent with their epithets. They range from the cherry palm of the Caribbean, *Pseudophoenix sargentii,* to the vase-shaped Sargent cherry of East Asia, *Prunus sargentii.* In 1915, yet another plant was given the Sargent moniker when Arboretum taxonomist Alfred Rehder recognized the Arboretum director by providing a name for the hybrid between the English oak, *Quercus robur,* and the American chestnut oak, *Quercus montana* (formerly known as *Q. prinus*). While hybrids between these two members of the white oak subgenus (*Lepidobalanus*) had been known since the 1830s, this was the first time the taxon was recognized officially with its own name, *Quercus* x *sargentii,* the Sargent oak.

From *Q. robur,* the hybrid attains a certain nobility and majesty, not to mention a girthy trunk, broadly spreading canopy, and distinctive auriculate (earlobe-shaped) leaf bases. From *Q. montana* come the crenately toothed leaves, smaller-stalked acorns, and, with age, coarsely furrowed bark.

The Sargent oaks that grow in the Arboretum's living collections can all be traced to the initial lot of acorns collected from a magnificent tree at Holm Lea, Sargent's estate in Brookline, Massachusetts. The seeds arrived at the Arboretum on October 6, 1877. They germinated and yielded multiple seedlings that were planted in the permanent collections and cataloged under accession number 5883. Currently, three plants (A, B, and C) remain in the collection, each looking exceptional for being over 130 years old. Perhaps the most spectacular is 5883-A, a majestic specimen located near the junction of Bussey Hill Road and Beech Path, at the base of the *Forsythia* and *Syringa* collections. With a current height of 84 feet (25.6 meters) and DBH (diameter at breast height) of 55.7 inches (141.5 centimeters), this tree commands attention. Visitors strolling down Beech Path often pause in awe to admire the tree's massive limbs and rounded crown. Recent landscape renovations to this area, known as State Lab Slope, will not only maintain the health and vitality of this specimen and the surrounding plantings, but also improve visual access. I should note that its siblings (plants B and C) may be slightly smaller, but are also notable and worth a visit. Both are located further along Beech Path, near the edge of the *Fraxinus* collection.

Q. x *sargentii* is extremely rare in cultivation, and our understanding of it is essentially limited to the specimens grown in our collection as well as those of a few other botanical gardens and arboreta. Certainly, our three trees are exceptional and have stood the test of time, but it would be premature to say much more without further study. I am particularly interested in this hybrid's potential use as a tree tolerant of the vagaries of the managed landscape, especially in urban areas where soils are prone to drought and other limitations. As *Q. montana* is an upland species typically found growing in dry and rocky habitats, one could hope that the Sargent oak is similarly tough. Oaks are difficult to propagate clonally, and attempts over the years to clone the Arboretum's trees have been in vain. However, because *Q. robur* is a species that can sometimes be rooted from cuttings, Manager of Horticulture Steve Schneider and I are conducting several experiments to see if ease of propagation from this parent was passed along to the hybrid. If that is the case, it opens up a great deal of potential for additional study and, perhaps, the Sargent oak's use as a street tree near you.

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For additional information on this hybrid and its interesting history, see: Hay, I. 1980. Outstanding plants of the Arnold Arboretum: *Quercus* x *sargentii. Arnoldia* 40(4): 194–199.