Forestry GIS Journal

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GIS for Forestry and Timberland Management

In This Issue

Burn Permit Tracking System GIS Web Tools Give Complete Picture

Georgia Forestry Commission's Burn Permit Tracking System provides real-time information to landowners for permit issuance and reduces wildfire risks during prescribed burns. Georgia's initiative to increase prescribed fire and associated benefits has led Esri to develop the special supported tool.

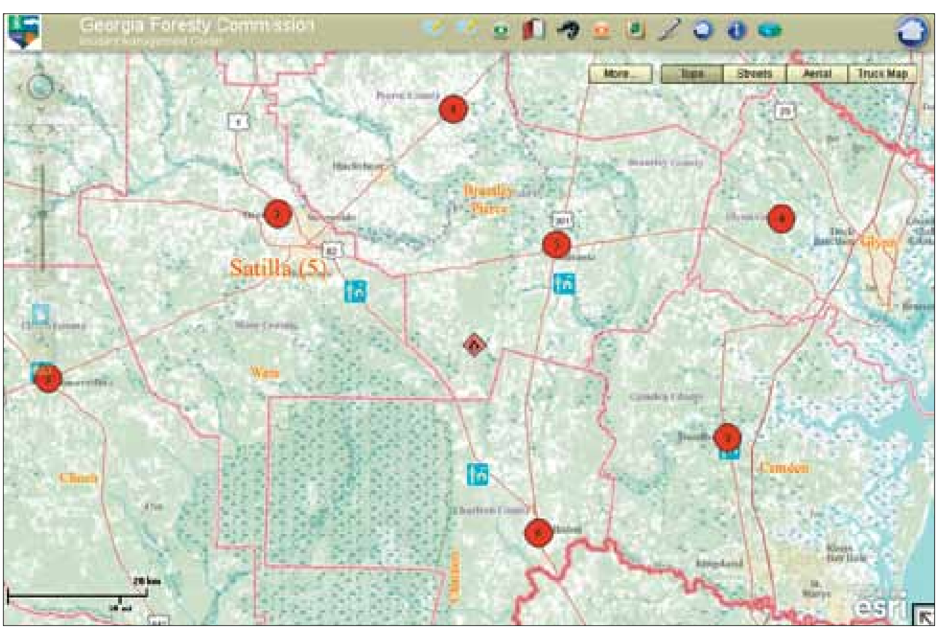
"Controlled fires benefit the forest," explains Alan Dozier, Georgia Forestry Commission's chief of forest protection. "The Esri web solution manages digitized burn permit data, provides real-time maps of permitted burning, and helps us perform spatial analysis. This is necessary for effective smoke and fire management planning."

The Burn Permit Tracking System is a new way of tracking fires. The innovative system helps rangers promote the ecological benefits of prescribed fire and make more informed decisions. It expedites the permit request process by enabling 24-hour availability and provides easy access to data and reports through Internet-connected devices including smartphones.

Georgia Forestry Commission has used Esri technology for many years as a tool for forest management and to fight forest fires. The development of the Burn Permit Tracking System will greatly expand the commission's use of geographic information systems (GIS). This GIS tool is the first of its kind. It shows the commission's current fire activity and tracks locations and the amount of acres burned from year to year. The Burn Permit Tracking System's GIS web tools allow users to easily add the location of wildfire events and manage the deployment of staff and fire suppression resources for forest fire management.

"Georgia Forestry Commission's Burn Permit Tracking System demonstrates how web mapping is being used to significantly improve the delivery of services to landowners while making the process easier to ensure environmental compliance," notes Peter Eredics, Esri's forest industry manager. "This system will also improve response time during wildfire events, which will result in fewer losses and safer working conditions for field crews."

The tracking system is built on Esri's ArcGIS Server architecture using ArcGIS API for Flex. ArcGIS Server accepts data from multiple sources and spatially locates the permits in real time. It shows the user information about the location such as weather, wind, and humidity. Rangers can make intelligent decisions about permit issuance based on the most current data. Forestry workers can use



A fire incident map shows the location of a current fire and the nearby fire management resources.

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Save the Date

Esri Forestry Solutions Conference
May 24–26, 2011
Redlands, California, USA
esri.com/forestry

Esri International User Conference
July 11–15, 2011
San Diego, California, USA
esri.com/events

SilviLaser 2011
October 16–20, 2011
Hobart, Australia
www.Silvilaser2011.com

Society of American Foresters National Convention
November 2–6, 2011
Honolulu, Hawaii, USA
www.Safnet.org/natcon11

Forest Day 5
December 4, 2011
Durban, South Africa
www.forestsclimatechange.org

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Burn Permit Tracking System

the Burn Permit Tracking System to generate summaries of permitted fire activity, compare permit parameters, and see relationships of permit requests and air quality needed for complying with state environmental mandates.

See the Esri-powered Burn Permit Tracking System on the Georgia Forestry Commission website at http://gfcgis.gfc.state.ga.us/permitentry/.

Data about prescribed burns is accessible through GIS.

Esri News

Esri International User Conference Resource for Forestry

Esri invites you to the Esri International User Conference. At this conference, you will see how GIS can help you better manage your forestry operations and business. Foresters will present ways GIS has helped them improve their workflows, manage forest inventories, create plans, reduce costs, increase revenues, and meet their forestry objectives.

- Learn how ArcGIS 10 combines imagery and GIS for land-use and trend analyses.
- See ways that enterprise GIS supports users in the field and in satellite forestry offices.
- Hone your skills at the GIS technology tracks; meet with the largest gathering of GIS consultants in the world; and find the solution you need, from road building solutions to contract management to market scenarios.
- Build your professional network by attending the Esri Forestry Group meeting.

When: July 11–15, 2011
Where: San Diego Convention Center, San Diego, California, USA
Learn more and register: esri.com/uc

GIS for Wildlife Management Case Studies Available

A collection of stories about how people are applying geospatial technologies to better understand biodiversity and animal threats, *GIS Best Practices: Wildlife Management,* describes best practices from around the world and shows ways GIS has been used to

- Respond to invasive species.
- Manage and facilitate disease prevention.
- Minimize mortality.
- Determine wildlife movement and habitat ranges.

Read it online or download this free booklet at esri.com/wildlife-bp.

Rayonier's GIS Strengthens Asset Management Capability

Forest Business Flexibility Improved by Esri Enterprise License Agreement

Rayonier Inc. signed an enterprise license agreement (ELA) with Esri, enabling the international forest products company to improve land management of its 2.4 million acres of sustainably managed forests. By securing unlimited access to GIS software, Rayonier managers can make more informed and timely decisions about their timberlands while preserving the environment through sustainable forestry. Rayonier is the first timber real estate investment trust (REIT) in the nation to shift to this easy GIS software acquisition method.

The ELA software program simplifies procurement of essential GIS technology that supports Rayonier's business decisions. With the benefit of unlimited software deployment, Rayonier now has the flexibility to apply the exact geospatial solution needed to support key business processes. Rayonier planners and land managers can apply the technology to a wide range of forest management activities, including applications for site preparation, planting, stand maintenance, timber sales, harvest compliance, and land administration. "In the face of changing markets, we need flexibility in our approach to land use and land management," explained Eric Fanelli, Rayonier's director of Land Support Services. "The ELA with Esri will help us bring together our forest management systems for a complete picture of our timber and nontimber assets. It will also help us quickly take advantage of business opportunities as they arise."

"This ELA emphasizes our commitment to our relationship with Rayonier," noted Peter Eredics, Esri's forest industry manager. "We see Rayonier's innovative approach as a new standard for using geospatial technology to redefine and advance positioning on the forest products value chain. It supplies a fully integrated system that lets you easily author and analyze data, maps, and models for desktop, browser, or field mobile device applications."

Rayonier manages Pinhook Swamp in North Florida using sustainable forestry practices.

J.D. Irving, Limited, Deploys Enterprise GIS

By Joy Chan, ESRI Canada Limited

J.D. Irving, Limited (JDI), was the first forest products company in North America to use Esri technology. The family-owned company, based in Saint John, New Brunswick, Canada, provides diverse products and services in forestry, transportation, shipbuilding, retail, and agriculture. Since 1983, the company has used Esri's GIS for forestry operations management of more than six million acres of land in New Brunswick and Nova Scotia, Canada, and Maine, USA.

In 2010, JDI completed an enterprise GIS deployment that has centralized geographic information throughout the organization and extended its GIS to other business areas. The new GIS platform allowed JDI to centrally manage workflows for its forestry operations, resulting in more efficient processes.

"Centralizing our geographic information into one enterprise system has created significant efficiencies and allowed us to create standards for managing GIS data and workflows," said Joe Pelham, IT Division, JDI. "The system has helped improve the quality of data and increased our capability for developing targeted applications to support the diverse needs of our various businesses."

The project began in 2007 and involved migrating numerous GIS applications and hundreds of datasets managed throughout 10 regional offices into a single geodatabase. Esri's ArcGIS technology provided JDI with comprehensive functionality for building the enterprise GIS. Hundreds of users view, edit, and distribute geographic information on servers, desktops, and mobile devices and over the web. The technology seamlessly integrates with other business systems, providing JDI with the capability to leverage GIS applications and data in its business processes.

The company also implemented Esri's job tracking software to improve workflow management for processes including harvesting timber, planting trees, managing wildlife habitat, building roads, and managing landownership. The software automates and tracks each job in the GIS workflow including loading field data, editing the enterprise geodatabase, and producing maps and reports. The system passes the job from one user to the next, prompting for input and approvals, until the entire workflow is completed. It improves user productivity by automating tasks and helps JDI effectively manage a dispersed workforce by distributing work geographically. Staff and management can view every stage of the workflow by job type, number, and priority. This capability increases accountability and helps staff create and assign work to the appropriate resources.

To enable its enterprise GIS deployment, JDI has an enterprise license agreement with ESRI Canada Limited that provides affordable, unlimited access to Esri technology and support.

First European Forest Group Meets

In October 2010, ESRI Deutschland GmbH hosted a conference solely for people who use ArcGIS for their forestry operations. People from 13 countries attended the event held at the historical Pantaleonsberg in Kranzberg, Germany. Because the conference was forest oriented, attendees were able to connect and offer their ideas in an environment conducive to sharing.

ESRI Deutschland conducted a preconference workshop that focused on ArcGIS Mobile technologies.

During the conference, participants discussed a wide array of topics such as forestry management solutions for government and private forest owners, remote-sensing analysis, and carbon trade. Representatives from European forest companies shared their experiences of using GIS to improve their forestry operations.

Keynote speaker Peter Eredics, Esri's forest industry manager, told the audience about Esri's longtime commitment to serving the foresters. Eredics was joined by Esri's Michael Miller in outlining a vision for the future of GIS in forestry. For example, they described the value of a mobile GIS and explained how disconnected editing can be synced with the server to add field data to the geodatabase.

Esri software distributors for the United Kingdom, Portugal, and Germany attended the event. GIS professionals talked about timber logistics—specifically, real-time tracking of forest trucks and how ArcLogistics optimizes routes and timetables. For instance, foresters can use GIS to schedule and route trucks to efficiently pick up full rather than partial loads. ESRI Deutschland's Marcus Hoffman discussed business-critical processes.

Representatives from CREASO GmbH showed how it uses ENVI and ITT Visual Information Solutions (ITT VIS) software image processing and analysis tools that integrate with ArcGIS to monitor forest health. In addition, Lenné3D GmbH showed how ArcGIS can generate a realistic visualization of the forest, highlight landscape change, and plan operations.

The Great Britain Forestry Commission representative explained ways its enterprise extends GIS and forest-specific applications throughout the commission. Its GIS can concurrently support 1,000 users.

Representatives of Coilte, which owns 445,000 hectares of land in Ireland, described how Esri's web-based tools help it meet requirements for Forest Stewardship Council (FSC) certification. Staff can identify community concerns and aspirations at an early stage and incorporate these into management strategies and practices, which is a condition of continued FSC certification.

GIS developers and experts described how GIS innovations are changing the forest management technology landscape. Solution partners in attendance included con terra GmbH, CREASO, Faculty of Geo-Information Science and Earth Observation (ITC), INFLOR (Brazil), Intend, Lenné3D, and Pöyry.

A con terra representative showed how forestry agencies can use ArcGIS to streamline workflows with a geodatabase, GIS processing tools, and model management.

ITC, a research institute in the Netherlands, developed the Integrated Land and Water Information System (ILWIS). The institute's representative promoted the value of geospatial data for driving forestry governance policies.

Attendees participate in hands-on ArcGIS Mobile projects in the field.

Foresters met in the beautiful Kranzberg countryside.

A representative of the software company INFLOR, which is Esri's first Gold Partner from the forestry industry, came from Brazil and presented INFLOR's enterprise forest management system software for online map services. INFLOR also provides Software as a Service (SaaS) subscriptions.

BaySF representatives invited people to one of its managed forests just outside Munich. In a mountain hut, presenters gave demonstrations of mobile applications at three outside stations equipped with ruggedized laptops and PDAs. Participants were encouraged to try out the software on these devices and complete forest-related tasks such as performing forest inventory, managing logistics, monitoring hunting activity, and recording pine beetle infestation. Delegates were able to experience a bona fide application in a real-world environment. The conference concluded with an excursion in the Bavarian Alps, where BaySF's board member Saul Walter gave the closing address that included the company's various operational challenges and successes.

"We are deeply grateful to BaySF and ESRI Deutschland for putting together this wonderful event," said Eredics. "This conference provided a collective body of GIS forestry knowledge in Europe that is not offered by any other event. Its success was due to its hosts and a community willing to share".

Participants appreciated this opportunity to share ideas, collaborate, and connect with each other. It gave them an opportunity to learn from other GIS users in the forest community that have like experiences and face similar challenges. With a focus dedicated to forestry GIS, attendees took away solutions that they could use right away. They found the conference so beneficial that they made plans to meet again.

Esri European Forest Group plans to meet in Germany in 2011. ESRI Deutschland is coordinating facilities and dates and will announce them as soon as possible. Plan to attend. Watch for updates at esri.com/forestry.

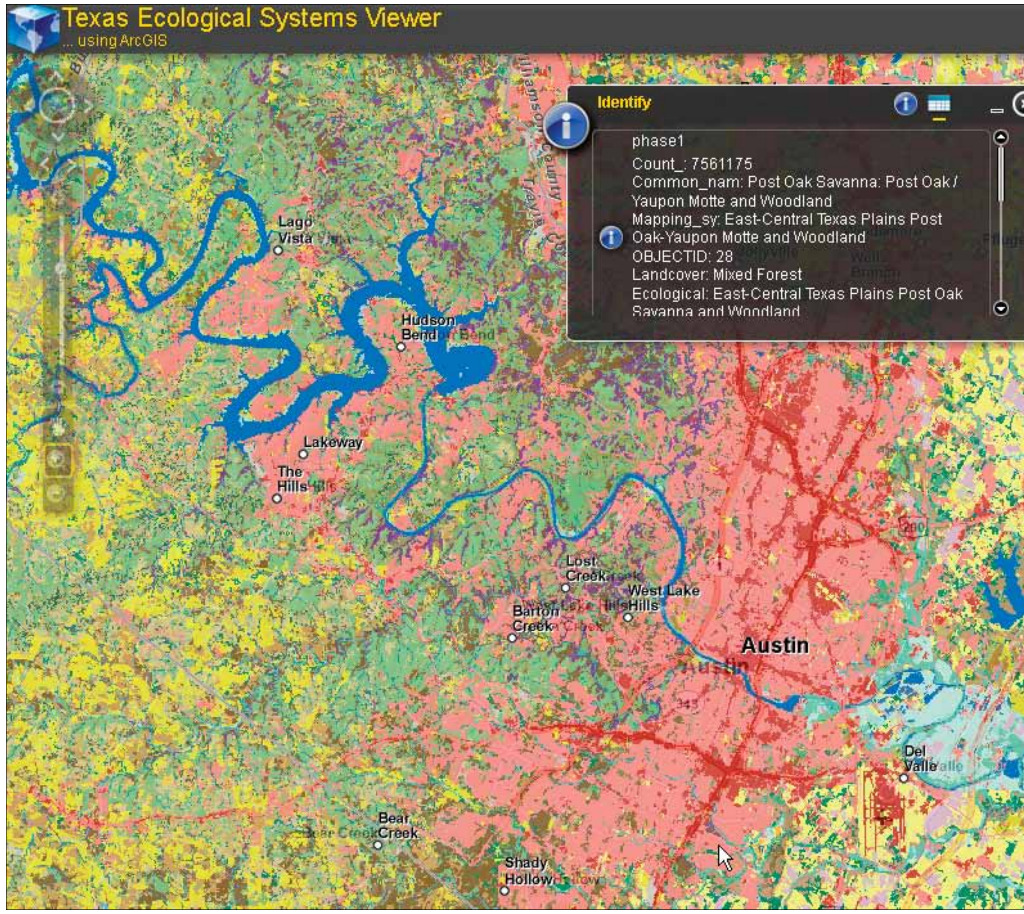
Experts gave GIS demonstrations in the forest at stations with GIS-loaded laptops.

Texas Statewide Vegetation Map

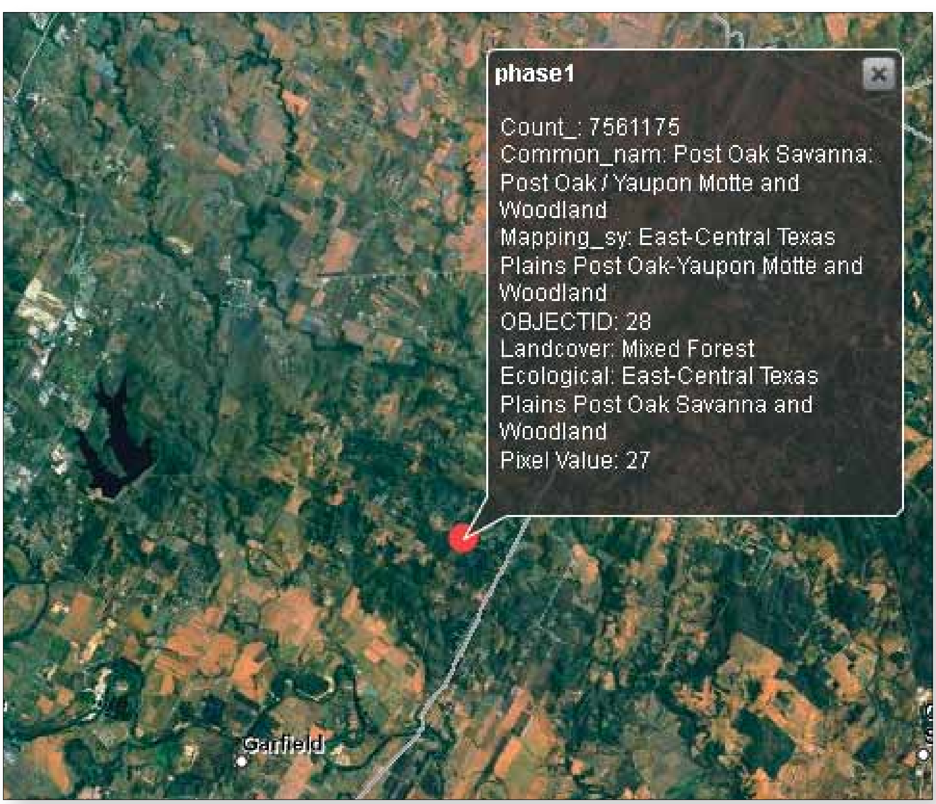
Vegetation maps are needed for habitat analysis, fire mitigation and response, water resource and environmental impact analyses, and more. These projects often include massive amounts of data, from lidar and aerial photography to ground GPS and classification work. Vegetation project data and output must be accessible to people in a way that they can use it.

The Texas Parks and Wildlife Department (TPWD) is using GIS to create a new land classification map of the state to get insight into the vast and diverse habitats and to comply with a state mandate. The department used Esri's ArcGIS to simplify this otherwise onerous task. The software made it possible for staff to use a complete system approach that includes data management, mobile data collection and in-field data analysis, rich analysis tools, and server technology for hosting map service applications that make interactive vegetation map data easily accessible from thin clients.

The department's Texas Ecological Systems Database Project produces vegetation datasets of Texas by section. The state is divided into six sections, and data is compiled for these in phases.



Texas Ecological Systems Viewer gives users a comprehensive picture of Texas land-cover types.

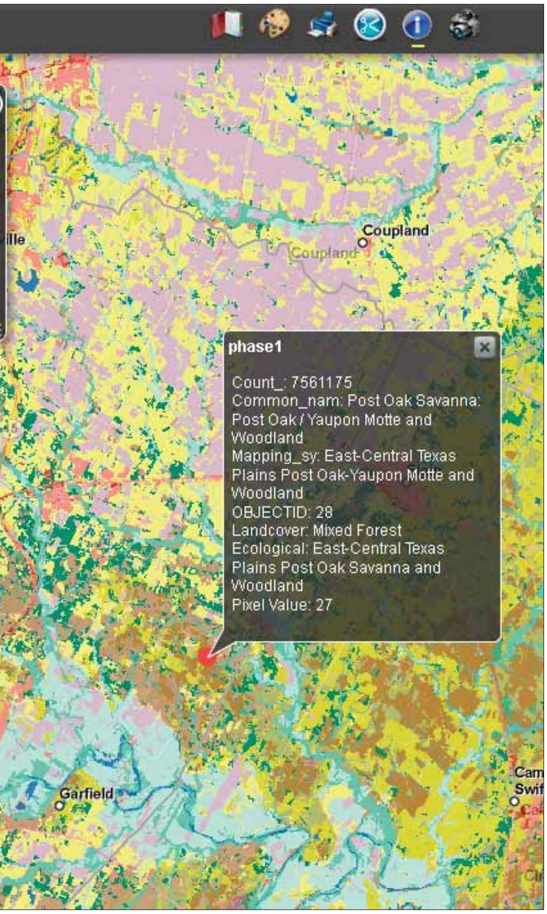


An Identification tool shows land-cover specifics of post oak savanna in east central Texas woodland.

Three phases have already been completed including the eastern half of the state. The data and maps are accessible online.

One of TPWD's goals for the project was to expand its user community beyond hard-core GIS users to include landownership, general land management, and academic communities. TPWD's GIS group, headed by Kim Ludeke, PhD, used ArcGIS Server and ArcGIS Viewer for Flex software out of the box to create web apps that aid data interpretation and dissemination. The outcome is a vegetation community map that is useful for planning and analysis at parcel and individual landownership levels.

Data, data, and more data has been the order every day of the project. Data comes from many sources such as The Nature Conservancy (TNC), United States Fish and Wildlife Service, Natural Resources Conservation Service (NRCS), and *The Geologic Atlas of Texas*, which contains 1:250K surface geology data for the entire state.



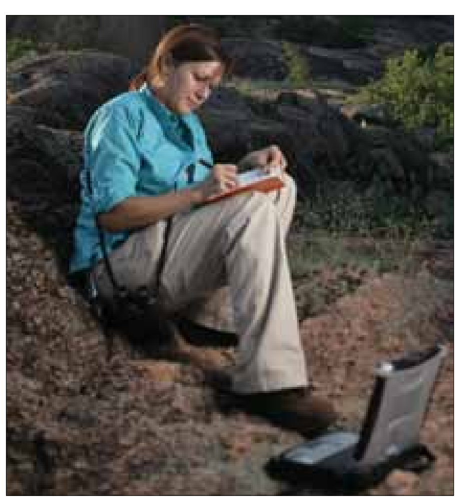
Amie Truer-Kuehn is TPWD's plant ecologist who works in the field identifying plant communities, storing her interpretation and documenting support. Working with ArcGIS Mobile, she has collected 10,000 ground truth data points from the field and loaded them directly into a file geodatabase. This data collection process, or ground truthing, involves a roadside survey of the plant communities. Avoiding urban areas, she selects areas of counties accessible via county roads. She is able to survey parks and wildlife properties and TNC properties more thoroughly because she can access these lands and has data sharing permissions.

While on the road, Truer-Kuehn stops every mile to collect data. She also stops for riparian zones and rare vegetation communities. The data she collects includes GPS location (latitude-longitude) and attributes of land cover (e.g., grassland, shrubland), cover percentage (wood components, herbaceous), dominant species (top three species), and ecological systems and subsystems. These attributes are listed in the vegetation map legend.

From the ground, it is hard to see the forest for the trees. Through the lens of her laptop, the ecologist has a comprehensive view of the landscape. She sees satellite imagery and aerial photography and uses a GPS while the mapping environment is open to get the complete context of the landscape in her immediate location. Furthermore, she can see underlying soils, slopes, digital elevation model (DEM) data, and one-meter true- and false-color infrared aerial photography, all of which has been loaded onto her laptop.

Using domains in the file geodatabase, Truer-Kuehn manages data input from the field and performs data cleanup on-site. She can upload her data to the project's GIS platform from the field or from her hotel room at night. The domains simplify the task of parsing out data to different partners who do other analysis and spatial segmentation of the data.

The GIS group uses ArcGIS Online basemaps for the project's map service. ArcGIS Server performs raster processing in the web app. Using ArcGIS Viewer for Flex, staff created an ID tool that can be used in a browser, enabling the light client user to turn on a vegetation layer, ID a pixel, and select various base layers. The user can also turn the vegetation layer off; look at the underlying aerial photography; click in an area; and while looking at true-color photography, see the vegetation type.



A field-worker uses ArcGIS Mobile to record land-cover and do ground truthing.

The Texas Ecological Systems Database Project allows users to perform a host of studies. For example, TPWD is using it to evaluate the quality of riparian vegetation. Considering USGS-defined hydrologic units and vegetation data layers, project analysts use GIS to see where riparian corridors are thriving and assess the impact that reservoir projects have on different vegetation types. They also see how much water is needed to maintain the ecosystems of various floodplains, in-stream ecosystems including fisheries within the banks, and the riparian areas along stream banks.

The department's Inland Fisheries Division uses GIS to study data related to an endemic bass species—the Guadalupe bass. This fish is only found in the smaller, clearwater streams and rivers of two watersheds in the hill country of Texas. Staff use map data to manage and create plans for watershed area management and improve stream quality for the bass.

The project helps the department comply with a Texas legislative mandate, Senate Bill 3, that requires that the department study the state's water resource needs and different aspects involved in water planning. TPWD uses GIS to model the water supply limits for estimated population growth, which provides strategic information for reporting and planning.

The Texas Forest Service taps the Ecological Systems Database Project for fire risk modeling as well as forest management projects such as a long-leaf pine restoration project. US Forest Service also accesses the database project to find rare species by using rare plant and animal species modeling.

TPWD's next ArcGIS upgrade and the addition of the ArcGIS Server Image extension will add more functionality to the web application. From the browser, users will be able to click and send data as they need it. TPWD plans to do another statewide vegetation project in 10 years to compare vegetation change.

Funding for the Ecological Systems Database Project was provided by the US Fish and Wildlife Service State Wildlife Grant program and the Texas Water Development Board StratMap program.

Managing Trees at the San Francisco Botanical Garden with GIS

Golden Gate Park in San Francisco, California, was developed in the late 1800s as a recreation area where city dwellers could escape to the outdoors. Throughout the 1,017-acre park, large maturing trees, such as Monterey pine, Monterey cypress, and blue gum, were planted to secure what was then the sand dunes that made up the western part of the city.

Located within the park is the San Francisco Botanical Garden at Strybing Arboretum. The garden is a 55-acre horticultural refuge where plant collections from other parts of the world, such as Chile and Australia, are cared for under the impressive canopy of pine, cypress, and gum trees.

While on a walk through the garden, an anonymous donor, who used the garden as her classroom, recognized the potential risks the maturing trees posed to visitors. Many of these giants contained large dead limbs or other structural defects, which predisposed the trees to branch, stem, or root failure. Coordinating with the San Francisco Botanical Garden Society, the donor provided the funding to tackle this large problem.

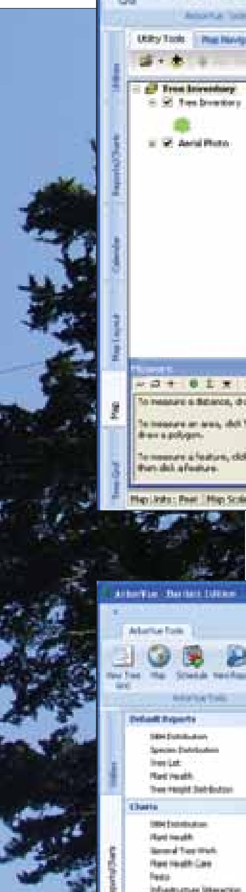
Bartlett arborist Dave Anderson removes a dead Monterey pine at the garden.

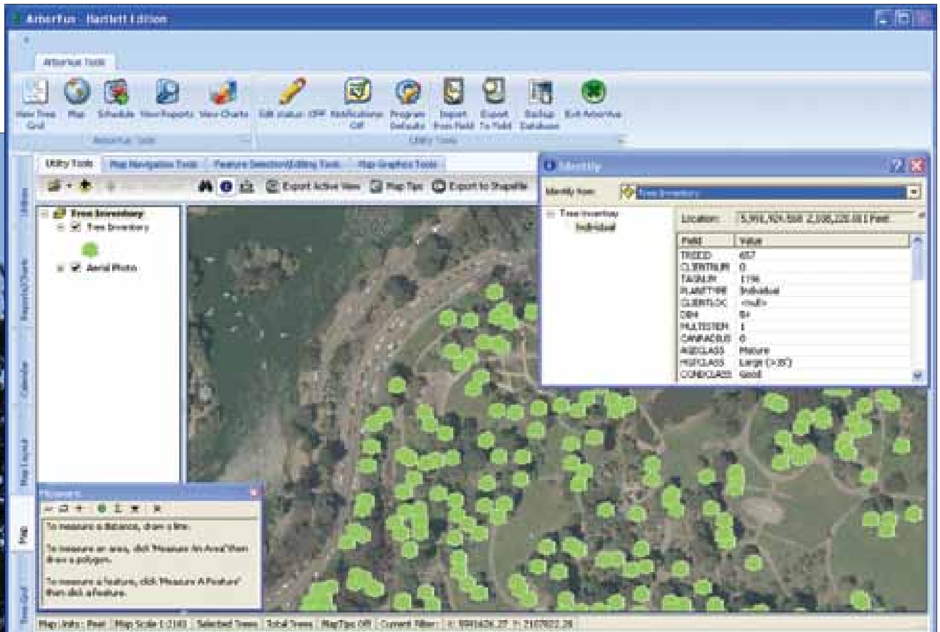
Bartlett Tree Experts, based in Stamford, Connecticut, with research laboratories in Charlotte, North Carolina, was called in to help remediate the probability of personal injury due to tree failure at the garden. On their initial tour of the garden, representatives knew that hundreds of person-hours of work would be needed to complete all the required tree pruning, support system installation, and removals. To properly plan, organize, and prioritize the work, a tree inventory would need to be performed.

One of Bartlett's many services is conducting GIS-based tree maintenance inventories. Its staff worked with garden personnel to define the goals and objectives of an inventory of the arboretum. The focus of the inventory would be all trees 18 inches and larger in diameter at 4.5 feet above ground level or any tree that showed visual evidence that it may fail. Using ArborVue, arboriculturally focused GIS software built with Esri's ArcPad and ArcGIS Engine, not only would tree attribute information be recorded (e.g., tree species, diameter, health), but recommendations for improving tree stand health and structure (e.g., pruning, structural support system installation, or tree removal) would also be included. Furthermore, the recommendations would be prioritized using a visual risk rating system while in the field. Recommendations for further tree evaluation were made for instances where it was difficult to tell from the ground whether a defect in a branch or stem warranted abatement treatment.

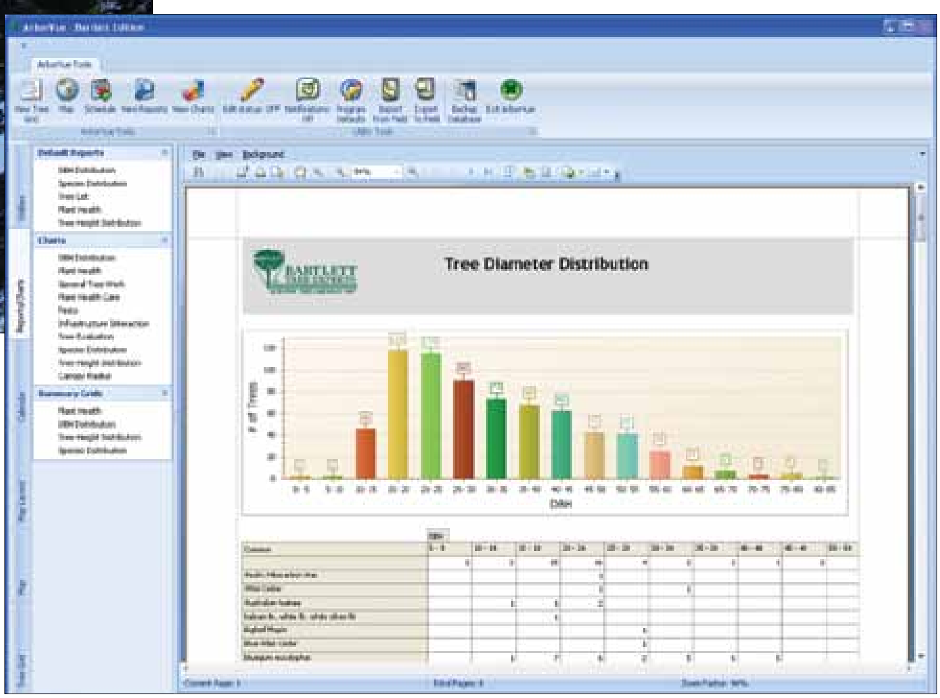
GIS support specialists/International Society of Arboriculture (ISA)-certified arborists from Bartlett's laboratories teamed up with the local Bartlett representative and a consultant from HortScience, a horticultural consulting firm based in Pleasanton, California, to form the two inventory teams that would complete the job. Using ArcGIS, the GIS specialists overlaid a CAD drawing of the garden on digital content obtained from GlobeXplorer Inc., an Esri partner. Using the newly created map, the garden area was equally divided among the teams of arborists. Each team carried a Trimble Geo 2005 series GPS/data recorder with a Trimble GeoBeacon to capture all the tree attributes and maintenance recommendations.

The tree inventory was performed during the first week of March 2007, and after a week of exploring the garden's large trees, data collection was completed. In total, the teams captured attributes for 710 trees in the inventory. Although the majority of the trees were Monterey pine *(Pinus radiata)*, Monterey cypress *(Cupressus macrocarpa),* and blue gum *(Eucalyptus globu-*





GIS integrates the many tasks involved with tree care inventory and management.



A wide range of reports, charts, and summary information gives the user information about tree metrics and tree care activities.

lus), the teams recorded a total of 132 different tree species.

The goal of the inventory was to recommend removal of hazardous trees and make recommendations for maintaining the safety, health, and structure of the mature tree canopy. It was determined that 140 trees (19 percent) needed to be removed because they posed potential hazards or were in advanced stages of decline. In addition, 513 trees (73 percent) needed to be pruned for safety, health, structure, or appearance. Another 47 trees (6 percent) needed tree support systems installed or inspected to reduce branch and crown failure potential. To assess sound wood strength, 33 trees (4 percent) required further quantitative tree structure evaluation. Tree diseases such as pine pitch canker, pests such as stem-boring beetles, and soil conditions were also recorded during data collection to help manage the trees in the garden.

With field data collection completed, a management plan was developed with work type recommendations grouped together and prioritized. The GIS specialists generated maps to illustrate where trees were located, along with the associated recommendations. Further queries were developed and illustrated on maps to show daily work and progress. As with most large organizations, there were numerous other projects going on at the same time as the tree work. Using GIS developed for the garden, tree work projects could be reprioritized around other projects taking place. Additionally, garden staff made all tree inventory information and maps available to the general public, and 30-day removal notices were posted to diffuse any public concern.

To date, most of the high-priority trees and areas of the San Francisco Botanical Garden have had the recommended work completed. Thirty trees, from 15-foot stumps to 200-foot trees, have been removed, and 150 trees have been pruned or had structural support systems installed. A total of $452,500 had been donated and has been invested in the garden, including the tree inventory/management plan, all the work associated with the pruning and removals, and the tree succession planting plan.

It is worth mentioning that not long after high-priority tree pruning and removals were completed, a severe storm hit the city. Many trees in the region were felled or badly damaged. Throughout the 55-acre San Francisco Botanical Garden, only five trees were lost or damaged, and these trees were in low-priority areas of the garden. Garden officials credit the work prescribed and carried out through the GIS model of the management plan as the reason there was so little damage to the garden compared to the rest of Golden Gate Park.

For more information, contact Patrick Anderson, GIS support specialist, Bartlett Tree Research Laboratories (e-mail: panderson @bartlett.com; tel.: 704-588-1150, ext. 127).

Mapping the Future for Emerald Ash Borer Readiness and Response Planning

By David Sivyer, Forestry Services Manager, City of Milwaukee

Communities threatened by Emerald Ash Borer beetles are aggressively pursuing best practices for early rapid detection and management including improved reconnaissance tools (geospatially accurate forest risk maps) and new suppression strategies. Emergent research and frontline intelligence are needed to develop improved management strategies for the beetles. Communities removed from the advancing front share a time advantage needed to evaluate and integrate new tools aimed at slowing the spread of the pests. Fundamentally important to both management strategies is the need for an accurate risk assessment.

Hyperspectral imagery and GIS detects and locates the city's ash trees, a species easily infested with Emerald Ash Borer beetles.

Aloft in a lift truck, city foresters use handheld spectrometers to capture canopy-level spectral signatures. This improves the accuracy of detecting ash tree species and segmenting them in 4-band multispectral imagery of the forest canopy layer.

The City of Milwaukee, Wisconsin, has a multifaceted strategy for Emerald Ash Borer readiness and response planning that is highly dependent on an accurate host inventory. The city's spatial street tree inventory identifies the number, size distribution, condition, and location of ash trees at risk.

City foresters armed with current street and park tree inventory data can easily quantify the number of ash trees at risk and evaluate various management strategies. However, communities like Milwaukee, which have statutory responsibility for abating dead and hazardous trees on private property, need other tools to more fully assess community risk associated with aggressive invasive forest pests such as the Emerald Ash Borer. To quantify the number of ash trees and associated ecological service values at risk in the community, Milwaukee conducted an i-Tree Eco project (www.i-treetools.org) in 2008. This study estimated the citywide ash population at 573,000 trees, representing 17.4 percent of the urban tree canopy and providing $221 million and $600,000+ in structural and annual functional value, respectively.

Although knowing the total number of ash trees at risk was helpful as a planning tool for assessing community risk related to canopy loss impacts, projecting associated wood waste volume, and forecasting budget and staffing needs, the specific locations of trees were needed to effectively manage an Emerald Ash Borer outbreak. To solve the ominous task of locating 573,000 trees in the sights of a rapidly advancing enemy, the Milwaukee Forestry Division looked to an emergent remote-sensing technology called hyperspectral imagery (HSI).

Airborne HSI is an advanced digital imaging process that uses high-powered sensors to record hundreds of contiguous narrow bands of electromagnetic energy reflected from objects or materials on the earth's surface. Each source, such as green and white ash, yields a unique reflectance or spectral signature, based on the molecular and electromagnetic properties of the substance, that can be targeted and extracted from the hyperspectral data.

This project applied advanced geospatial technology, including high-resolution remotely sensed hyperspectral imagery and lidar data, in conjunction with GIS analytic applications, to develop new tools needed for improved species mapping, risk assessment, forest health monitoring, rapid early detection, and management of the beetles.

The specific objectives of the project were to

- Use HSI to geospatially map the location and condition of ash species in the Milwaukee area with 80 percent or greater accuracy.
- Develop replicable protocols for ash species identification in urbanized areas using remotely sensed HSI.
- Integrate HSI-derived ash species maps with existing GIS analytic tools to provide specific property ownership and contact information for ash tree locations throughout the city.
- Evaluate the use of HSI in conjunction with the Urban Forest Effects (UFORE) model for predicting the volume of wood waste generated by a pest outbreak.
- Use remotely sensed HSI to establish new best practices for beetle and invasive species risk assessment.

The project was completed in four steps—field HSI data collection and analysis, airborne HSI and lidar data collection, HSI data analysis and processing, and target data integration with GIS analytic tools.

Ground and airborne HSI and lidar data were collected simultaneously in August 2008. Milwaukee forestry staff partnered with a team of remote-sensing experts from ASD, Inc.; RFP Mapping LLC; and SRA International to collect canopy-level spectral signatures from ash species as well as several other common trees and background vegetation in the Milwaukee area. The spectral signatures were collected with a handheld spectrometer from a lift truck positioned at the top of the canopy to minimize potential differences in spectral radiance or reflectance readings between the handheld spectrometers and airborne sensors due to leaf placement in the crown.

Team experts with many years of experience working with multiple sensors and hundreds of targets found ash to be the hardest target to separate from its background with limited false alarms (incorrect species classification). Data classifications are significantly more complex in urban areas because interference, or noise, is created by an array of surface materials. To facilitate the ash classification in Milwaukee, the team utilized hyperspectral imagery rescaled to 4-band multispectral imagery to create a base forest canopy layer. This segmentation of forest canopy from nonforest vegetation increased ash classification accuracy by limiting HSI analysis to pixels within the area of interest only.

SRA International analyzed the hyperspectral data using spectral signature exploitation, proprietary algorithms, and analysis methodology. Hyperspectral feature analysis modified with spectral angle mapping technology was also used to identify ash trees at various stages of health and growth and reduce false alarms.

Lidar fusion with the hyperspectral data improved the positional accuracy of the hyperspectral imagery and resulted in a high-precision tree polygon layer and a tree point dataset with tree height, crown width, and stem diameter attributes. Remote-sensing specialists on the team use GIS analytic tools to convert the HSI raster data into a vector data format. The vector data was merged with tree point data from the lidar extraction to improve classification confidence of individual ash trees based on polygon attributes. The resultant GIS ash layer enabled the ash classification to be overlaid on the city's GIS parcel map, which provided address-based location and property owner information for ash tree locations in the city. GIS integration also supported a comprehensive urban tree canopy analysis to quantify existing urban tree cover and available planting area on an aldermanic district and citywide basis.

Following initial delivery of the GIS ash classification layer in March 2009, the project team worked with the Milwaukee Forestry Division to conduct an initial accuracy assessment (ground verification). In-scene spectral comparison of approximately 2,000 confirmed ash trees suggested an overall ash classification accuracy approximating 80 percent, with honey locust, various maple species, and red oak constituting the majority of false alarms. Subsequent adjustments to the spectral angle mapping process yielded a modest reduction in false alarms and increased the ash classification accuracy to 84 percent.

Armed with an HSI-derived GIS ash classification layer, the Milwaukee Forestry Division initiated an extensive door-to-door outreach campaign during the summer of 2010 to confirm the presence of ash and prescribe beetle risk and management options for more than 26,000 parcels identified with ash trees. During 2010, approximately 12,000 households (parcels) were inspected by urban forestry and horticulture college interns. In addition to verifying the presence of ash, outreach crews were tasked with recording any ash trees the imagery did not identify.

Fifty-two percent of the properties inspected in 2010 were confirmed with ash trees. This fell short of the 84 percent ash classification accuracy projected based on in-scene imagery comparison with 2,000 verified ash trees. Even though the project failed to meet ash classification goals, the imagery did accurately identify 99 percent of all confirmed ash trees. Two species, silver maple *(Acer sacharinum)* and honey locust *(Gleditsia tricanthos)*, accounted for 42 percent of all false positive species. Field verification results will be returned to the project team for further analysis and adjustments to algorithms and methodologies in hopes of improving ash classification accuracy.

The vast majority of residents contacted had no idea they had an ash tree, nor were they aware of the attendant risks or management options for the Emerald Ash Borer. It is hoped that the increased awareness and opportunity for advanced planning will lead residents to take appropriate action to either treat or remove their ash trees in advance of infestation and reduce the public safety risks accompanying an outbreak.

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