Forestry GIS Journal

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GIS for Forestry and Timberland Management

In This Issue

U.S. Forest Service Speeds Access to Forest Data

The U.S. Forest Service (USFS) has been using geographic information system (GIS) technology in various forms throughout its nine regions in the continental United States and Alaska. Public lands in USFS' national forests are vast, encompassing 193 million acres. GIS helps USFS meet long-term natural resource management goals for these lands.

The USFS Southwestern Region includes Arizona, New Mexico, and parts of Texas and Oklahoma, with a total of 11 national forests and 3 national grasslands. It has finished its migration and implementation of a geodatabase. This makes it easier for the region's ArcGIS users to manage data, perform analyses, and generate reports and maps that are useful to managers and resource specialists for making decisions about land management activities.

The region's GIS is a distributed enterprise system, with each national forest having its own GIS geodatabase. Because all these geodatabases have been built using the same standard, forests can easily share data with the regional server, which is located in Albuquerque, New Mexico. This makes it simple for forest managers to quickly access ecological data throughout the region and develop both local and regional views of forest and grasslands. This improves development and implementation of the forest plan. GIS users can monitor land use and natural resources, analyze heritage and cultural sites, assess watersheds, and support other USFS activities and missions.

The GIS enterprise system puts geographic analysis into the hands of forest personnel and provides natural resource data to the public. Getting to the point of reaping these advantages takes work, because it takes time and effort to develop standard data dictionaries and schemas. In addition, shapefiles and coverages need to be migrated to the geodatabase.

The GIS program manager for the Southwestern Region, Candace Bogart, explained the work involved. "It took our team of five people three and a half years to complete the data migration. We designed a data dictionary of about 15 themes. Working with the Tennessee Valley Authority and Esri, we were able to set up data standards. We made all the

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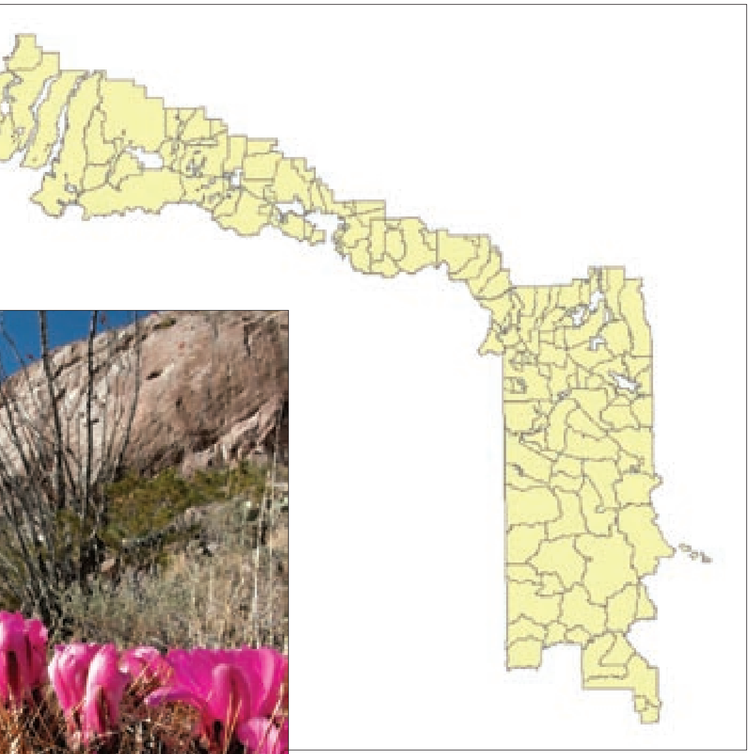

The USFS Rangeland Allotment data layer helps foresters understand land use.

Cactus flowers color southwestern landscapes. (Photo courtesy of USFS)

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U.S. Forest Service Speeds Access to Forest Data

data digital and put everything in the same format. For instance, we converted all the roads data to match the guidelines in our data dictionary. We did that for 15 themes. There are about 1,200 quads per theme, so that's 20,000 quads of information that we digitized and can now use in GIS."

A geodatabase is the common data storage and management framework for ArcGIS. It allows USFS to store a rich collection of spatial data in a centralized location. Users can apply sophisticated rules and relationships to data and define advanced geospatial relational models such as topologies and networks. For example, the region has used these capabilities to create off-road vehicle scenarios for planning purposes. GIS shows relationships of low-density stream crossings, types of motorized vehicles, watersheds, topography, and so forth. So far, the Prescott and Lincoln national forests have completed their motor vehicle use maps. These have been posted on the National Travel Management Web site. Now the GIS group is working on similar maps for the other nine forests.

A geodatabase enables users to maintain integrity of spatial data with a consistent, accurate database. It provides a multiuser access and editing environment. This capability is highly valuable, since each forest is responsible for its database management and editing. Quality assurance tools from Esri's Production Line Tool Set (PLTS) for ArcGIS were very useful for the project. Bogart explained, "We use these tools to design our geodatabase with QA/QC rules for topology and other needs. For example, we included coincident and vertical integration rules as part of the geodatabase. This helped us check if range allotments were vertically coincident with a forest boundary. This tool eliminated a lot of problems. We even used PLTS for ArcGIS tools for migrating our coverage data into the geodatabase. Once we moved the coverages into the geodatabase, we then pushed the geodatabase schema out to every forest's geodatabase." The functionality of PLTS for ArcGIS is now part of Esri Production Mapping.

GIS team members wrote the migration strategies and scripts and used a data loader tool to migrate the data. Foresters then attended workshops by Esri Professional Services so they could implement GIS for their individual forests. When the region's GIS team updates the central geodatabase scheme and the data dictionary, the update is done for everyone as an enterprise activity.

With the geodatabase now in place, more than 450 USFS staff members use the enterprise GIS. Training has played a key role in the success of the program. USFS contracted with a local vendor, AllPoints, to write a training program and hold workshops. Participants work with their own forestry data in class and are therefore able to start working on their projects immediately. It has been much easier and more efficient for the Southwestern Region to contract with AllPoints for the training program than to have its own staff conduct this training.

"AllPoints was very flexible, designing the training to our needs," Bogart said. "Its people offered some very helpful advice. They also designed some new tools that helped us leverage our data and move into analysis and tools development."

Each forest supervisor's office has its own server; each uses the geodatabase standard and dictionary for data management tasks. The regional office in Albuquerque has a central AIX server that brings the distributed data together. This production geodatabase is accessed by the forest GIS users via the internal network. If, for instance, the GIS team needs to do road editing for an area in the Coronado National Forest, it accesses the Coronado regional office's geodatabase. Because the structure of each forest's geodatabase is the same, the data is easy to access and use. Data is served at a scale of 1:24,000.

The geodatabase supports different elements of GIS data used by ArcGIS. For a riparian mapping project, Forest Service ecologists wanted to know the location and attributes of the Southwestern Region's riparian vegetation. Because this region has a lot of desert area, it is important to know where the riparian areas are to monitor and preserve them. Digital elevation models (DEM) were used to calculate valley bottom models and construct indexes for wetness, adjacency, and steepness to create a data layer of valley bottoms. Another layer contains vegetation data. A relationship of valley bottoms and vegetation was shown for a watershed. Large-scale aerial photography was also added to the project. Polygons were drawn to more easily delineate the valley bottom on the imagery. Identifiers of vegetation inventory showed species type such as cottonwood and willow. By bringing imagery, inventory, and models together in the GIS, the user obtains a strong visualization of occurrences and relationships. In addition, these maps and imagery established a baseline to monitor vegetation changes in the future.

Making data available to the public is also an important part of the GIS staff's work. Using PLTS for ArcGIS, members export their region-wide and individual forest datasets to shapefiles and post them on the Web site for public consumption. Scientists, people from universities, and contractors can go to fs.fed.us/r3, click on GIS, and use the datasets for research and business purposes. The Southwestern Region is using ArcGIS for forestry inventory and land management planning. An online interactive map helps staff access this information for developing a forest plan. Forest plan information is posted and viewed by the public via a GIS viewer at maps.fs.fed.us/kaibab/mapviewer.jsp, which provides basic tools for panning, zooming, and layering data.

Bogart, who provided much of the information for this article, acknowledges the work of Geospatial Services Technology Center and especially Aaron Stanford, who created a template for the forest plan revision site that enabled the R3 data to be dropped into the template and uploaded. USFS Southwestern Region's planning staff member Reuben Weisz and the R3 GIS staff also contributed.

Read an overview about Esri's geodatabase technology at esri.com/geodatabase.

See the Whole Forest—
A Holistic Approach to Forestry Management

Remsoft is helping forestry and timber companies meet complex business planning challenges. Andrea Feunekes, its CO-CEO, recently sat down with Esri's *Forestry GIS Journal* editor, Barbara Shields, to talk about the changing landscape of GIS for forestry management.

Esri (Shields): What do you think is the best business model for meeting today's forestry challenges and building plans that ensure a successful future?

Remsoft (Feunekes): Successful management always considers sustainability and requires a holistic approach to building a business model for making intelligent decisions. You should look at the whole picture, not just trees. Foresters need to put plan objectives such as wildlife, sustainability, carbon sequestration, and environmental certification into that picture. The effective business model allows foresters to make the best possible decision and be assured that they have included everything. Remsoft software is based on linear programming and mathematical optimization technologies so users can create various decision scenarios. They can explore those scenarios and assess the impacts of variables such as interest rates, gas prices, and carbon credit exchange policies and make decisions based on that information.

Esri: How does GIS play into this holistic approach?

Remsoft: GIS plays two significant roles. First, as Esri always says, "Geography matters." GIS allows foresters to see where things are and their spatial relationships and better understand the impact of choices that are being made. What's going to be harvested? Where is it going to be harvested? What features are located near something else and how are they related? What are the restrictions on a cutover? Second, [with] the application of linear programming and advanced analytics, GIS creates the basis for spatial optimization to make well-informed choices. For example, two cutovers cannot be next to each other because of opening size restrictions. Foresters who consider tens of thousands and, often, hundreds of thousands of different polygons can do so more effectively and efficiently using advanced analytics in GIS technology.

Esri: How does GIS support spatial optimization within a forestry company's business management model?

Remsoft: Spatial optimization is the next place for GIS to go. Foresters understand the value of decision optimization. Spatial optimization means making decisions within your business planning context that are relative to what is where. It goes beyond simply knowing where things are to choosing what to do based on location. When you are looking at specific situations and you want to incorporate them into plans on a forest-wide level, you have a lot of polygons to consider. You need an advanced analytics process to help you make those decisions. You tell the model the constraints you have to consider and objectives to attain. The model helps you decide what, where, and when timber is harvested while enabling you to comply with, for instance, sustainability practices, habitat and biodiversity constraints, and financial goals.

Government regulations and industry forest management standards contain spatial parameters. If these should change—should a new policy not to harvest near water courses be introduced, for example—these constraints are easily added to the model.

Esri: What changes are you seeing in the way forestry companies are using GIS?

Remsoft: GIS has come of age. It is at an infrastructure level. GIS should not be restricted to single projects; rather, it should be integrated into every part of the forestry business. Remsoft software solutions are robust and allow users to build models for planning and scheduling that enable our clients to add more considerations into their decision-making processes. Sustainability planning, conservation, and harvesting should not be taken on as individual projects. These should be included in the whole analysis so that you truly know you have explored a space and have a clear understanding of what you are doing. GIS is a core business solution that provides the basis for you to stand in front of your stakeholders and explain the reasoning behind your decisions and planning and to prove it.

Esri: Since Esri's ArcGIS 10 is an integrated system, how do you foresee this changing the way foresters do business?

Remsoft: ArcGIS opens up huge collaboration opportunities. Remsoft's latest platform release, Remsoft Analytics, is designed for collaboration. Geospatial modeling is complex, and a lot of people cannot operate at that level, nor should they be expected to do this. But they do have a lot they can add to the discussion. For example, a forester in a regional office has valuable local knowledge and may know that a certain polygon should not be harvested. That person needs to be able to feed this information into the company's forest database.

Remsoft clients are moving now to a much more collaborative, simple-to-use, inclusive technological framework. Using optimization, they can achieve their goals in forestry, attach climate change initiatives, create conservation plans, and set aside animal habitat. With optimization, forest and timber organizations can have it all.

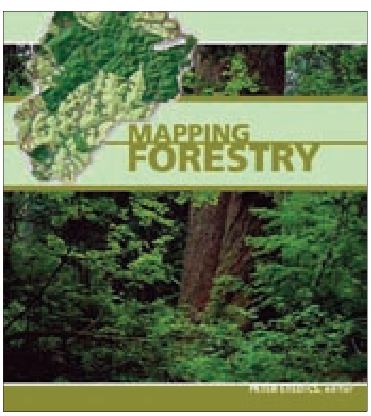
Remsoft recently joined Esri's partner family. A highly regarded software developer, Remsoft has a client list that includes Carter Holt Harvey; F&W Forestry Services, Inc.; JD Irving; Rayonier; Timberlands Ltd; and Washington State Department of Natural Resources. Remsoft clients employ geospatial optimization to sustainably manage more than half a billion acres of land worldwide, achieving certification including sustainability issues in their forest management plans. Most of Remsoft's clients use Esri's technology.

Learn more about Remsoft at remsoft.com.

Mapping Forestry

A beautiful set of maps and descriptions created by people working in the forestry industry from around the world is presented in the Esri Press book *Mapping Forestry*. From logging feasibility to operations management to sustainability planning application, GIS increases productivity and efficiencies. *Mapping Forestry* highlights GIS-produced forestry maps developed for a full range of research, planning, and operational forestry activities. In addition to maps and descriptions, contributors offer recipes for map-building success for you to follow in creating similar GIS projects.

Editor: Peter Eredics
Esri Press, 2010
80 pages, $39.95
ISBN: 978-1-58948-209-8



Join Esri Forestry Group

Esri Forestry Group (EFG) is a network of forest, timber, and woodland Esri GIS users who share their insights and experiences.

- Collaborate with peers.
- Interact through conferences, meetings, webinars, and user forums.
- Follow geospatial technology trends.
- Get the *Forestry GIS Journal* online newsletter.
- Share successful GIS projects for the forest industry.

Learn more and join for free at esri.com/efg.

GIS Foresters: What Are You Thinking?

Join the GIS conversation via social media:
ArcGIS Blog—Discussion about various Esri software and industries at blogs.esri.com
Community Maps—ArcGIS Online Maps and Apps for Everyone at arcgis.com
Spatial Roundtable—Conversation on select topics by experts at spatialroundtable.com
Esri Video—Videos about Esri technologies at video.esri.com
Esri Ideas Site—Community suggestions for ArcGIS software enhancements and improvements at ideas.arcgis.com
Twitter—Latest forestry GIS and Esri Forestry Group news at twitter.com/esriforestry
LinkedIn—Esri Forestry Group information and questions at LinkedIn.com
Esri TV on YouTube—Demonstrations and training at youtube.com/esritv

Esri Career Opportunities

Consultant/Project Manager—Natural Resources/Environmental
Use your consulting and project management experience in the natural resources and environmental markets to help clients transform real-world needs into state-of-the-art, GIS technology-driven solutions. This is a challenging opportunity to lead project teams and manage the entire GIS implementation process. Learn more and apply at esri.com/careers/consulting.

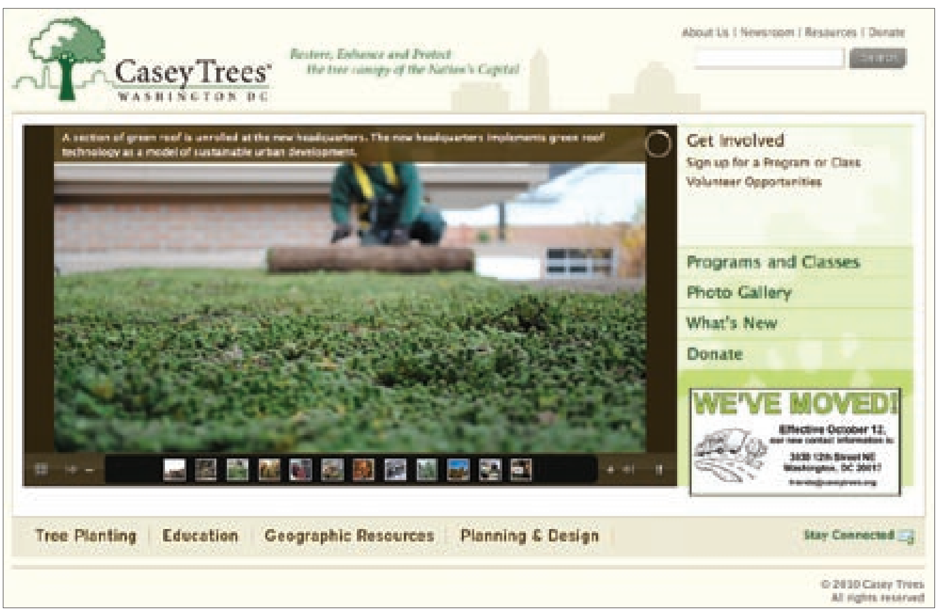
Agriculture Industry Solutions Manager
Use your years of experience and knowledge to assess and identify practical applications of GIS in the agricultural field. This is a challenging opportunity to provide coordination and management of Esri's strategic marketing and solutions efforts as they relate to the development and use of GIS products and services within the agricultural market. Learn more and apply at esri.com/careers/enviro and search for jobs in "agriculture."

Foresters' Work Acknowledged at Esri UC

Esri presented its Special Achievement in GIS (SAG) award and commended forestry, timber, and woodland organizations for their outstanding work using GIS. The winners include

- Casey Trees, which built the Casey Trees Web site on ArcGIS Server and used Flex to build applications that highlight the 7, 000 trees in Washington, D.C. (The site hosts user-friendly but data-rich, high-end interactive online maps. See the Web site at caseytrees.org.)
- Ministry for the Environment, New Zealand, for developing a geospatial solution for measuring and tracking land-use change for monitoring carbon stocks of New Zealand's forests and soils
- University of California, Davis, Arboretum, which has been leading a nationwide team of botanical gardens and zoos staff to build a GIS that makes these scientific collections more accessible

Esri applauds the efforts of these agencies' use of GIS to intelligently visualize, analyze, and manage forests, timber, and woodlands.



Save the Date

Esri Federal User Conference
January 19–21, 2011
Washington, D.C., USA
esri.com/feduc

Esri Developer Summit
March 7–10, 2011
Palm Springs, California, USA
esri.com/devsummit

Esri Forestry GIS 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/uc

Lidar Analysis for Forestry

Esri recently published the white paper *Lidar Analysis for Forestry* that explains how ArcGIS can be used to manage and analyze lidar data in forestry applications. Author Gordon Sumerling of ESRI Australia Pty. Ltd. steps through processes to convert lidar data into a format ArcGIS can process, explains methods to interpret the lidar data, and shows how ArcGIS can disseminate the data to those who are not geospatial analysts.

Read this white paper on Esri's GIS for Forestry Web site in the Announcements section at esri.com/forestry.

Transparent Forestry in Ireland

By Myles Donncadha, Colm O'Kane, and Martin Stoecker

Coillte, Ireland's largest forest management company, struck out in a new direction by opening its forest management plans to public consultation using Web-based technology. Since 2008, it has been possible for the public to comment on the forest management plan and influence forestry planning operations via the Internet.

Coillte is a commercial company operating in forestry, land-based businesses, renewable energy, and panel products. The company employs approximately 1,100 people and was established in 1988. It owns over 445,000 hectares of land, approximately 7 percent of the land cover of Ireland.

This solution for public participation, called Forest Management Plan (FMP) review process, uses Esri and con terra GmbH Web GIS technology to provide digital area information about the planned forestry operations.

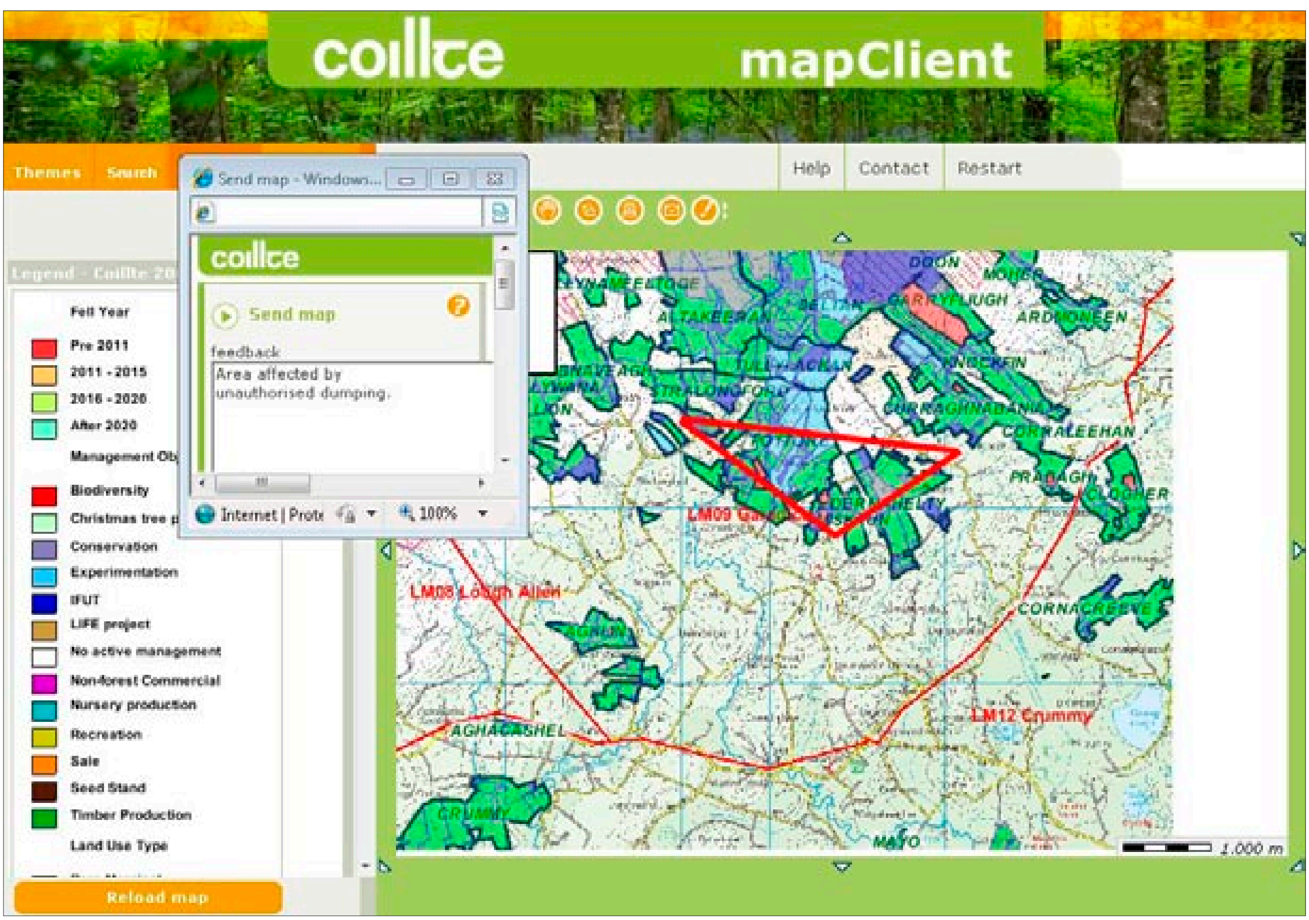
As the key holder to Irish forests and a commercial forestry and forest products company, Coillte has to make the final decision about the detailed operation of each of its forest sites. The management of the forest estate is done according to Responsible Forest Management (RFM) principles to balance the social, economic, and environmental aspects of Coillte's business. Local participation is one main pillar in the planning process. This input enhances forest managers' understanding of how decisions impact all forest users and neighbors, improves decision making, and helps create a positive working environment for staff and contractors.

Together with representatives of the responsible ministry and certification and environmental organizations, Coillte developed this public participation process. Each forest district informs its stakeholders directly and through national newspapers about the opportunity to examine and discuss the forest plans.

A Web solution developed and hosted by con terra GmbH (conterra.de) provides information about Coillte's forest management plans. It enables site visitors to submit suggestions and concerns regarding the plans. Coillte considers suggestions as part of the planning process and, if possible, incorporates them into the final forest management plans. The stakeholder is informed of the outcome.

Coillte staff uses the Web to efficiently organize the FMP review process. During the different phases of the process, all necessary information is provided online. Important components during this process are mentioned on the Web GIS, which shows users FMP information on the map.

Staff must log in with a password. A map window provides standard functionality for



Forest projects from biodiversity to timber production are shown on Coillte's forest application. A comment tool created by con terra makes it easy for the user to add comments.

spatial search, zooming, and panning to help the user understand points, lines, and polygons. The user can also add comments to selected objects and send them via e-mail, during the FMP review process, to the department responsible for the creation of the FMP. The e-mail address and further contact information of the user are integrated automatically so that requests are possible.

Besides the development of the solution, the hosting was also outsourced to con terra. The necessary Esri and con terra Web technology is provided via the Web hosting environment. For necessary updates or changes, the responsible GIS specialists from Coillte provide the actualized geodata; the hosting team from con terra actualizes the data and implements the necessary changes.

With this assistance, Coillte developed and released the first version of the solution in 2008 in just one and a half months.

The Web solution, which is based on Esri ArcGIS Server technology and con terra's sdi.suite, is intensively used by the Irish population. In the week after the official launch of the Web solution, more than 200 users registered.

For Coillte, the solution is an efficient way to provide access to its sustainable management plans, giving people the opportunity to comment and ensuring a transparent forest management planning process.

About the Authors

Myles "Mac" Donncadha is a forester and manager who has worked for Coillte since 1998 in research, GIS, IT, district management, and resource planning areas.

Colm O'Kane is a GIS analyst who has worked with Coillte since 2008.

Martin Stoecker is a GIS professional and forester who has worked for con terra since 2004 as project manager responsible for the forest and timber market.

GIS Used to Assess Algerian Forest Health

By Haroun Chenchouni and Abdelkrim Arar, University of Batna, Algeria

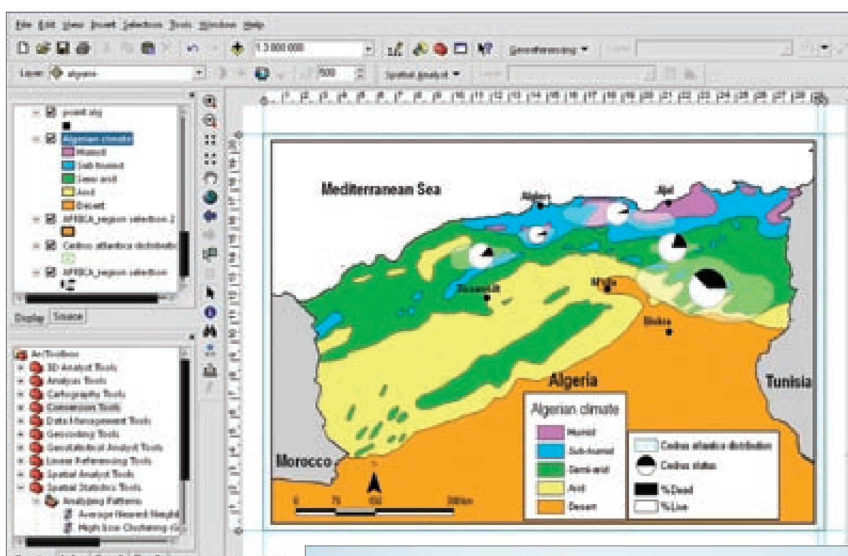
At one time, Northern Africa's Algeria was a forest region. Today, 85 percent of the area is classified as arid and semiarid, a condition perpetuated by irregular rainfall and frequent drought. Since 1990, an ongoing drought has menaced Algerian forests. The vast Sahara Desert encroaches on the northern region of the country's forested areas, where the greatest level of forest degradation is occurring. In some areas, forest dieback is at 100 percent.

For centuries, Algerian forests produced timber to build the massive ships that sailed the Mediterranean Sea. This industry often subjected the forests to overlogging, but they grew back. In the mid-'70s the government launched a vast reforestation program called *barrage vert* (meaning "green barrier"). But this time, the forest has not been resilient. Drought is drying up the forests, making them more susceptible to insect infestation and forest fire, leaving the desert to penetrate this fortification. Assessing the correlation between climate influences on the forest is a job for GIS.

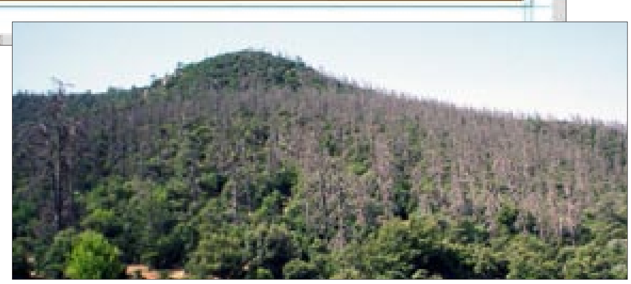
Algerian foresters use GIS primarily as a forest inventory tool. But GIS can do much more to study climate-to-vegetation relationships. It can be used to correlate vast amounts of information from remote sensing, meteorological measurements, and temporal evolution of a Normalized Difference Vegetation Index (NDVI). Researchers from Algeria's University of Batna are using GIS to study the relationships of climate and forest health. Acting as an early warning tool, GIS is used to see how the forest is doing and to create predictions based on this information.

Understanding at-risk areas is essential for intelligent forest management planning in Algeria. GIS stores forest data and repurposes it for many types of applications such as depicting areas of concern, calculating harvestable timber, and modeling the spread of forest fires.

For more information about this article, contact Haroun Chenchouni, scientist at the Department of Biological Sciences, University of Batna, Algeria (tel.: +213-779-462990, e-mail: chenchouni@yahoo.fr).



ArcGIS is useful for assessing the level of drought disturbance on forest plantation according to several factors such as climatic data.



The rise in earth's temperatures is linked to dying forests.

Canada Maps Deforestation

By Barbara Shields, Esri Writer

The United Nations, national governments, nongovernmental organizations (NGOs), and many others are striving to improve the planet's health by reducing greenhouse gas emissions. Forests play a major role in purifying the air because of their ability to absorb and store greenhouse gases such as carbon dioxide. Scientists use image processing tools and ArcGIS to exploit rich information content from satellite and aerial imagery, field measurements, and climate simulation models to calculate and report on the forest's carbon sequestration sources and changes.

According to the Woods Hole Research Center, the world's largest terrestrial carbon reservoir is its boreal biome. Boreal forests cover 14.5 percent of earth's land surface and contain 30 percent of its carbon. In boreal regions, such as Canada, extremely low temperatures also promote the formation of permafrost. The cold temperatures within permafrost reduce decomposition rates. This frozen organic soil releases relatively little CO_2.

Canada grows 10 percent of the world's forest cover and 30 percent of the world's boreal forest. There are approximately 347.7 million hectares of forests in Canada. During the past 35–40 years, Canada has converted 3.3 million hectares of its forestland to other uses, which is about 1 percent of its total forested area (figure 1).

Canada is a signatory of Kyoto Protocol and is obligated to report greenhouse gas sources and sinks associated with afforestation and deforestation. To do so, it has implemented a national forest sector carbon accounting system that brings together data from multiple resources including a national forest inventory, growth and yield data from sample plots, statistics on change agents, and land-use change calculated from remote-sensing data. The accounting method integrates image processing and GIS analysis to monitor deforestation and calculate the carbon storage and changes, which are essential for Canadian national assessments.

The process was begun by developing standards for consistency that can be used for data review across the country as well as meeting the measurement standards of the United Nations Framework Convention on Climate Change (UNFCCC), which is the international environmental treaty to which Canada has agreed.

Canada's forest carbon reporting system is called the National Forest Carbon Monitoring, Accounting and Reporting system. The Canadian Forest Service uses the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) within this system to estimate emissions and removals associated with land conversions to and from Canada's forests. Researchers use the Carbon Budget Model to assess carbon stock change over time. This model simulates forest carbon stocks in aboveground and belowground biomass, litter, dead-

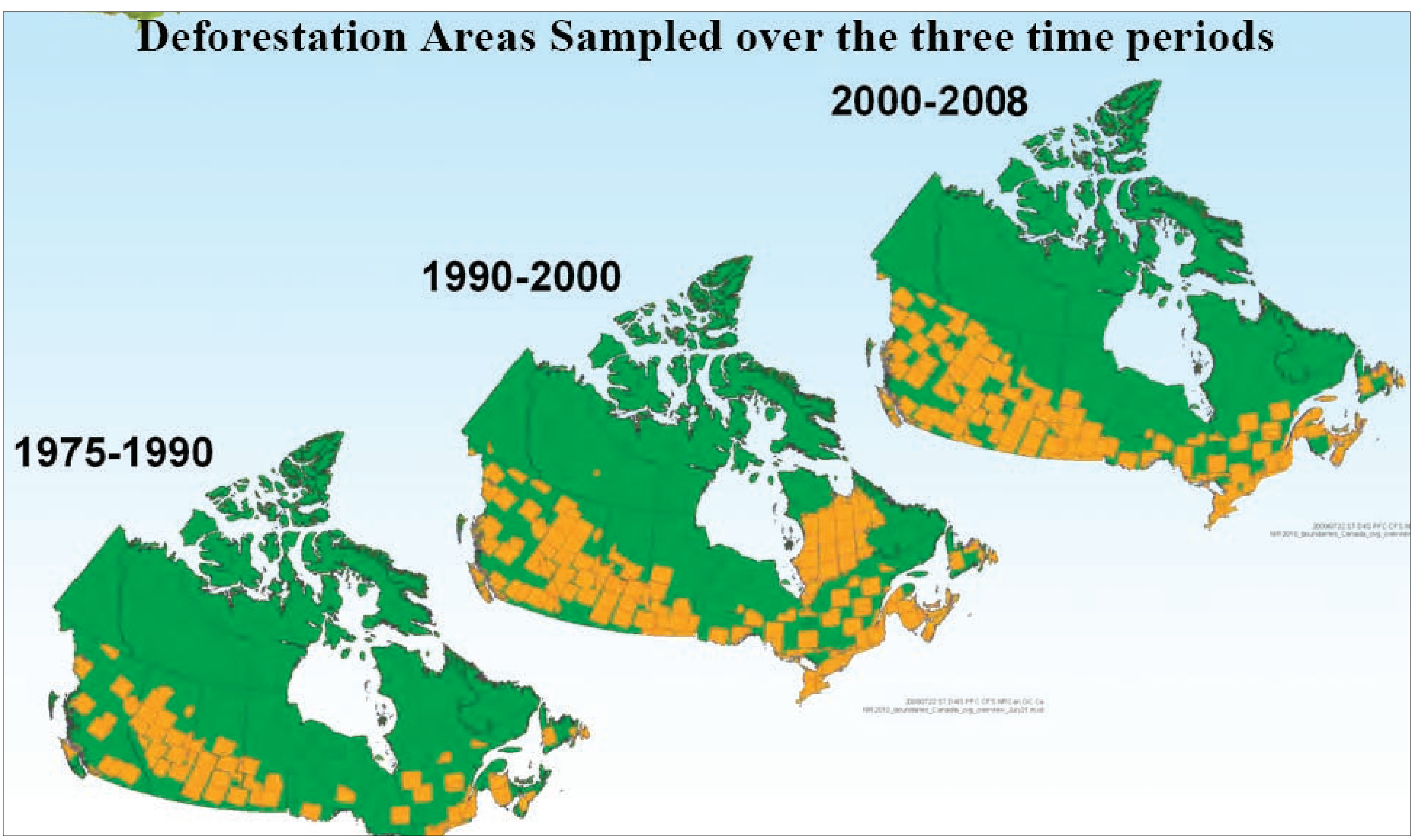


Figure 1. Canadian Forest Service maps deforestation to show where forests have been converted to other types of land use over time. Orange represents where sampling has occurred.

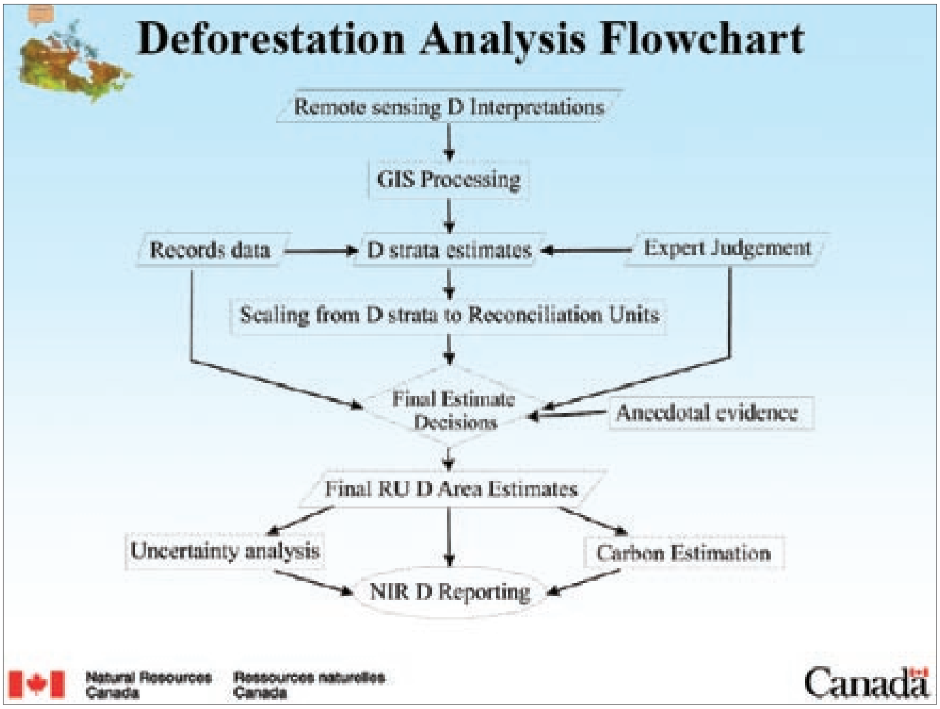


Figure 2. Carbon emissions and removals are calculated using remote-sensing data and GIS processing. This analysis is included in the National Inventory Report.

wood, and organic carbon soil. The results of analyses are included in Canada's annual greenhouse gas inventory and National Inventory Report (NIR). Estimates date back to 1990.

Natural Resources Canada—Canadian Forest Service (CFS) tracks what is happening to the country's forestlands—specifically, where and when deforestation has occurred and to what the forest has been transformed (figure 4). CFS monitors causes of land-use change such as from urban development.

The measurement of forest change provides factors applied to carbon calculation models required by UNFCCC (figure 2). This data also provides regulators and policy makers with a basis for developing sustainable forest plans.

The measurement process begins from above with Landsat imagery and aerial photography. Satellite imagery provides a means for spatially measuring land-use change. Temporal imagery of land-use comparisons reveals where the most change has occurred.

Landsat is an efficient remote-sensing data source for forest analysis. Landsat multispectral earth-orbiting satellites, developed by NASA, scan Canada's vast forests using sensors to digitally record reflected and emitted energy from the earth in various wavelengths of the electromagnetic spectrum and store it in an archive. This is an enormous amount of data to consider. To meet UNFCCC accounting requirements, CFS tries to sample the same areas repeatedly to examine change over time. The time periods used are 1975–1990, 1990–2000, and 2000–2008. Landsat multispectral scanner (MSS) was used for 1975, and Landsat Thematic Mapper and Enhanced Thematic Mapper Plus (ETM+) were used for subsequent time periods.

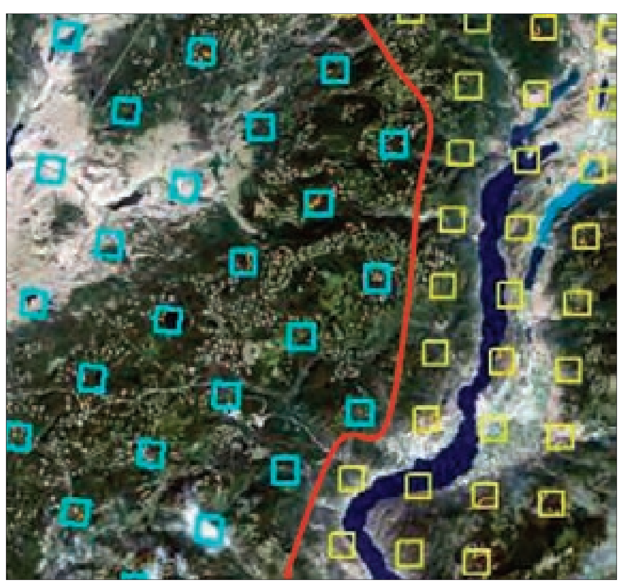


Figure 3. Data within these grid cell samples is compared over time. ArcGIS highlights areas of land change.

Spatial sampling methods also make accounting feasible. A grid is laid over the imagery, and cells within the grid are sampled to assess land-use change (figure 3). Sampling density varies depending on the expected rate of deforestation, and 6 to 12 percent of an area inspected may be sampled. The area for each deforestation event is rated against all the cells inspected and detailed in each deforestation category class.

Areas of change in the imagery are detected and flagged. ArcGIS shows where change has occurred, highlights potential areas of forest clearing, and compares imagery from different years. Then forestry specialists take over the interpretive analysis (figure 4). Events are classified in accordance with the Deforestation Interpretation Guide (DIG) provided by Natural Resources Canada. This way, everyone uses the same standard definition, which supports consistent interpretation across the country. To verify Landsat imagery interpretation, experts use aerial photos, forest inventory, road networks, gravel pit licenses, and oil and gas facility data. The imagery dataset contains more than 70,000 photos for land-use verification.

The deforestation monitoring group is working with Canada's National Forestry Information System (NFIS), which makes forest data available to the public. The public is invited to view and provide their local knowledge on deforestation events used in the calculation of Canada's deforestation rates. The site can be accessed at nfis.org/. Select Language, then "Public Input Deforestation". Create a new user and log in.

Esri and PCI Geomatics have now fully integrated their GIS and imagery capabilities to help GIS users

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Canada Maps Deforestation

make efficient use of their growing volumes of imagery datasets. To process its imagery, CFS uses Geomatica remote-sensing software, provided by PCI Geomatics, and ArcGIS. PFC also uses Geomatica's image processing tools to orthorectify and enhance Landsat imagery and build image stacks for change detection. ArcGIS is used for data management and analysis that support the understanding of forest events. CFS uses a Live Links tool linking the cursor position on both ArcGIS and Geomatica displays, thereby allowing the systems to be used simultaneously.

The convergence of GIS and imagery makes it possible for CFS to integrate imagery as core to GIS to meet its wide range of imagery requirements and maximize the value of its spatial data.

Resource managers use this integrated platform for imagery solutions as a complete system for managing, disseminating, visualizing, and analyzing spatial data. The valuable information provides the scientific basis for Canada's forest carbon accounting system.

CFS's carbon accounting team converts the deforestation area information for inclusion in the National Forest Carbon Budget Model. Environment Canada then assembles data on various greenhouse gas emissions related to forestry, agriculture, energy, and industry across Canada in its national greenhouse gas inventory calculations. It uses this information as it develops and publishes its National Inventory Report to meet the reporting requirements of UNFCCC.

Canada's National Forest Carbon Monitoring, Accounting and Reporting system has engaged provincial and territorial governments and private industry. Provincial and territorial governments have contributed to the project by mapping deforestation, supplying imagery and geospatial data, doing ground truthing, and giving expert advice. In addition, various consulting firms throughout the country have been qualified to provide mapping services based on the standard DIG methodologies.

Special thanks to CFS's Andrew Dyk (Andrew.Dyk@nrcan.gc.ca), Donald G. Leckie, and Sally Tinis for providing the information for this article.

Learn more about Esri's GIS solutions for climate change at esri.com/climatechange and forest management at esri.com/forest and PCI Geomatics imagery technologies at pcigeomatics.com. Read about the CFS carbon accounting team at carbon.cfs.nrcan.gc.ca/.

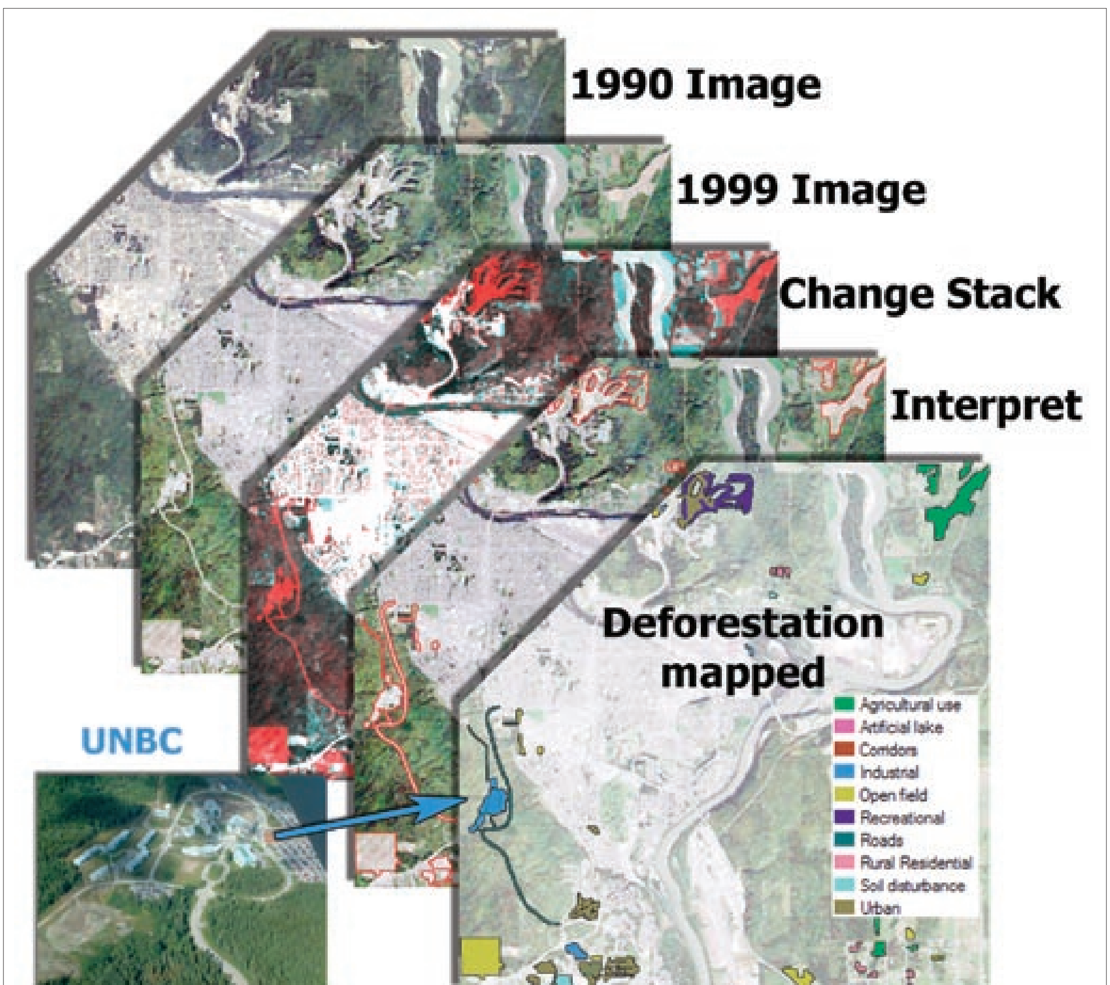

Figure 4.
This example shows the mapping of deforestation from the construction of the University of Northern British Columbia (UNBC) near Prince George, BC.

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Public Gardens Grow Research Capability with GIS

Public gardens come in many forms including arboreta, botanical gardens, zoos, display gardens, entertainment gardens, historical landscapes, and nature gardens. These gardens serve to connect visitors with nature, provide researchers with insight, and preserve plant species. The flora of these gardens is rooted in geography. GIS technology is helping public garden managers inventory, maintain, and manage their plant collections.

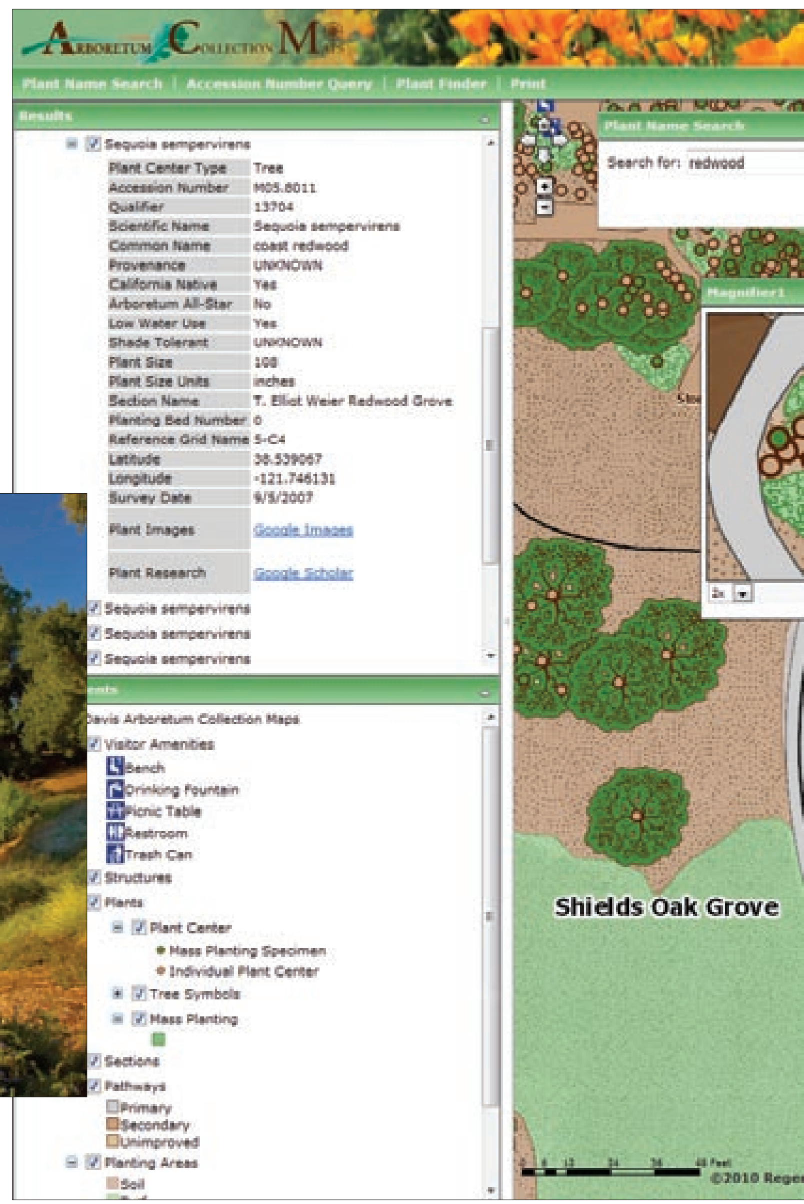
The University of California, Davis (UC Davis) Arboretum uses Esri's ArcGIS to keep track of and maintain its plant collection and facilities as well as help visitors, students, and researchers explore the more than 30,000 plants growing in its gardens. This program has been very successful.

UC Davis has also been instrumental in growing a consortium called the Alliance for Public Gardens GIS (APGG), an endeavor funded by the Institute of Museum and Library Services. APGG, an organization of more than 75 botanical gardens and zoos, is developing GIS standards for managing garden collections at an enterprise level. Some of its notable project partners include the San Diego Zoo, the Missouri Botanical Garden, and the Arnold Arboretum of Harvard University.

An outcome of APGG's effort is the ArcGIS Botanical Garden and Zoological Park Data Model. It is a free template designed for ArcGIS software that helps botanical gardens, zoos, and similar public landscape organizations implement their GIS projects so they too can easily map their plant collections and facilities. This important work will help increase the use and value of botanical collections and their role in plant conservation and education worldwide.

UC Davis Arboretum's GIS project provides an online, interactive mapping tool that offers search capabilities. Web site visitors can search for plants by name or by characteristics and see plant images. This research tool also allows people to link to scientific papers about selected species. They can locate a plant in the arboretum and print their own maps for customized tours of the garden that highlight their particular points of interest.

Visitors to the UC Davis Arboretum experience many types of trees, shrubs, and flowers that grow in harmony with the local climate. The Mediterranean Collection features plants that grow well in California's Central Valley. These are arrayed on a curving hillside around a scenic lagoon. The Australian Collection displays towering eucalyptus trees. The California Foothill Collection includes



A Web map shows redwood tree locations and provides specific species information.

UC Davis Arboretum's Mediterranean Collection (Photo courtesy of Allan Jones) valley oaks and native currants and gooseberries. Growing in the Conifer Collection are cone-bearing trees such as pines, cedars, firs, and other evergreens native to Japan, Europe, Mexico, and North America. A desert collection, East Asian collection, acacia grove, and many other plant habitats provide visitors with opportunities to connect with the natural world.

Brian Morgan, GIS manager of the arboretum, explains the research value of the GIS mapping application built on ArcGIS Server. "Scientists, faculty, and students research our collections. The system allows them to locate plants and easily access information about genetic backgrounds and relationships. Via the Web application, the user can click on the link, see images of a particular plant, and read scholarly articles and research papers about that particular plant."

The site provides users with various ways to search for more information. A user can explore the details of the plant by clicking on a plus tool on the map interface, typing a partial or complete scientific or common name in the search box, and/or clicking on an image link to see plant photos.

The project started in 2005, when Morgan implemented the arboretum's ArcGIS project. It took three years for university interns and staff to capture geographic location data for a geodatabase inventory of 30,000 different plants living within the 100 acres of the arboretum. They used a Trimble ProXH GPS receiver, a laser range finder, and ArcPad software to capture plant attributes and coordinates. Some plants, such as wildflowers, were grouped and located within a polygon, while others, such as trees, were recorded as individual features.

Once the geodatabase was complete, the team was able to create map books. This was done using MapLogic Layout Manager, which is an ArcGIS extension from MapLogic Corporation. It generates a professional-looking map book with key and locator maps, indexes, page numbering, and more.

Using an ArcGIS Server out-of-the-box template for making Web applications, the GIS team performed basic tool customizations tailored to the specific Web site needs of the arboretum. Once the site was up and running, users and evaluators made further suggestions for improving tools.

"We were able to easily add functionality to the Web site," notes Morgan. "For example, people wanted to have more information such as flower color or when a selected plant flowers. It took us about two hours to create a tool for accessing our database about California native species and making the database a part of the site's search tool. We will continue to make changes as we go along. For instance, we want to add editing capability for our own staff. We also want to link the system to our work order system, which would then be accessible via mobile devices. We have more to do, and our GIS is making this possible."

Experience the UC Davis Arboretum Web site at arboretum.ucdavis.edu. Get a free download of the ArcGIS Botanical Garden and Zoological Park Data Model at the Alliance for Public Gardens GIS Web site at apgg.org.

Mapping Presettlement Forest Species with Witness Trees

By Michael P. Strager, Division of Forestry and Natural Resources, West Virginia University, Morgantown, West Virginia; Melissa Thomas-Van Gundy, USDA Forest Service Timber & Watershed Laboratory & Fernow Experimental Forest, Elkins, West Virginia; and Michael M. Metz, Natural Resource Analysis Center, West Virginia University, Morgantown.

The original surveyors of West Virginia during the late 1700s and early 1800s used tree markers or other natural features as reference landmarks. These locations often referenced vegetation that existed before any European settlement and influence on the land. Such a vegetation dataset can provide a useful and interesting snapshot into the past to help understand the historical aboriginal forest. It could be possible to determine the species and mix that grew and matured optimally in a natural, untouched environment. The U.S. Forest Service recognized an opportunity with this historic information to reconstruct vegetation patterns to help better manage the land today for sustainable forestry.

Researchers at West Virginia University were also interested in exploring the ecophysical characteristics of a historic tree inventory to examine relationships to topographic roughness, moisture index, aspect, and landform. In addition, the site descriptions by species could be used to validate existing natural vegetation models or as an input to species prediction models. With the availability of this unique data and interest from both the Forest Service and the university, the goal of the witness tree project became to develop a GIS geodatabase of corner trees and other markers from the original survey tracts contained within the proclamation boundaries of the Monongahela National Forest (MNF) in West Virginia (figure 1).

A database of witness trees of the MNF was created using the ArcGIS georeferencing toolbar. We later incorporated the ArcGIS Spatial Analyst extension to determine terrain attributes. The Esri products were instrumental in the collection, mapping, and analysis of the witness trees by landform and physiographic subsection.

The first step in our methodology was to carefully scan the historic maps with a large-format scanner. Next, we used the georeferencing toolbar to link common features on the historical maps to features we could register already in our spatially mapped layers (figure 2). Fortunately, many maps included streams and tributary intersections that provided the necessary control tie points. By examining the link table within the georeferencing toolbar, we were able to make sure all our referenced maps had a root mean square (RMS) error of less than .009 inch, which represents the difference between the original location and the new one determined from the transformation process.

Figure 1. Location of the Monongahela National Forest in West Virginia

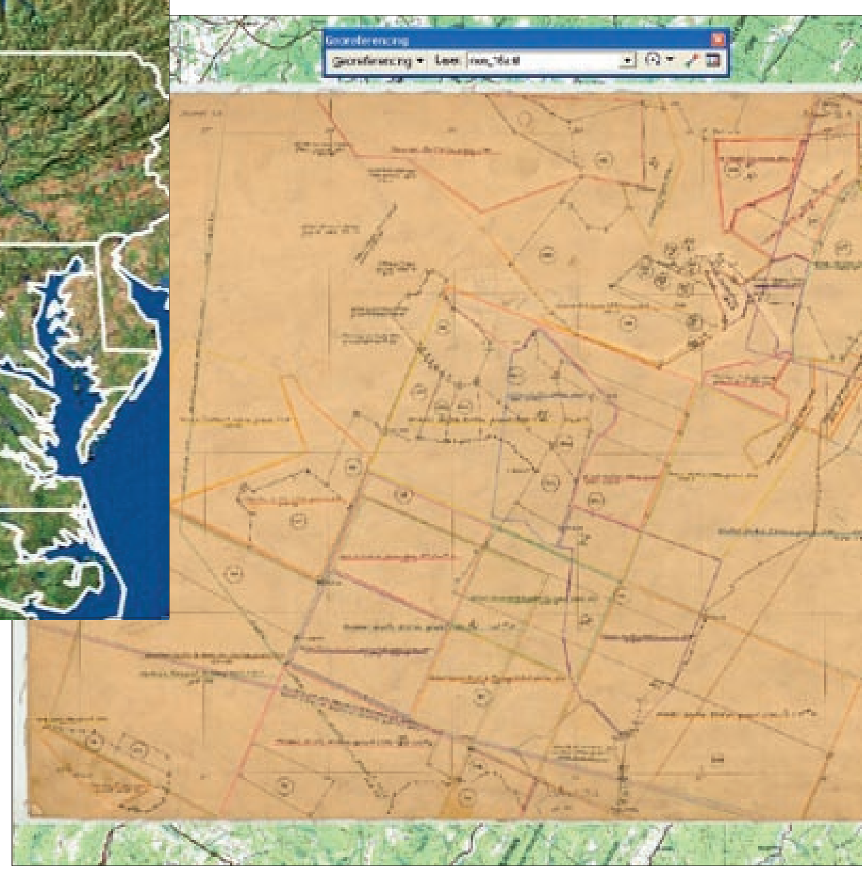


Figure 2. Georeferencing Toolbar within ArcMap

After the maps were referenced, we digitized and attributed all features using a consistent display scale of 1:5,000. Survey corner information we wanted in the database included location, type of corner (tree, river bend, pile of rocks, stake, etc.), tree species (if used), and any other pertinent tree data such as tree size.

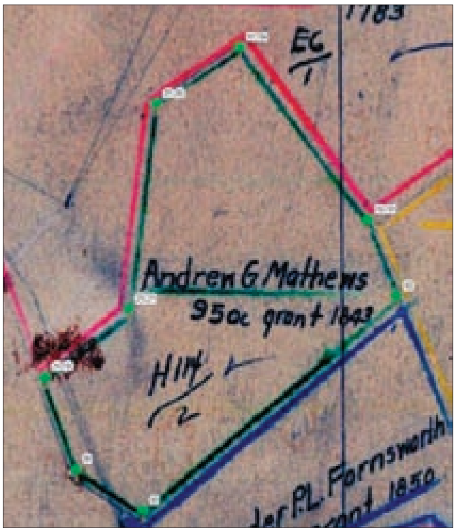
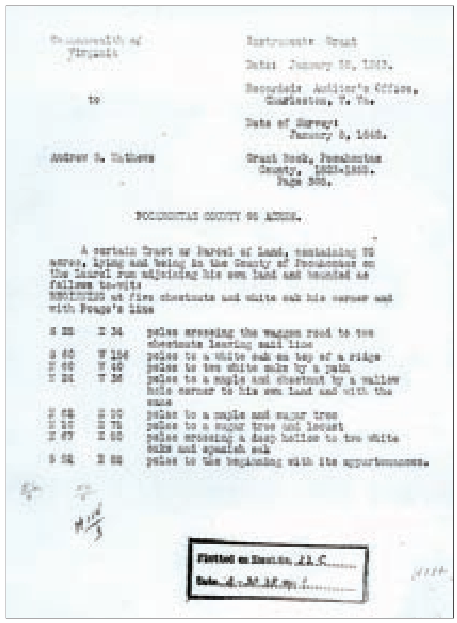


Figure 3. Old parcel survey map data was digitized to add boundary data for the GIS view of past forest conditions.

Common names used for tree species had to be related to common names likely to be found in old survey records. Each polygon that represented the first parcel surveyed for the area was also given a point referenced by the individual locator number, generally in the center of the polygon (figure 3). The deeds describing the parcels were used to determine survey corners on the maps and tally the tree species or other markers used to witness those corners in the attribute file (figure 4). Along with tree species, the locator number, date of the deed or survey, and deed holder's name were recorded in the ArcGIS geodatabase.



A certain Tract or Parcel of land, containing [illegible] acres, lying and being in the County of Pocahontas on the laurel run adjoining his own land and bounded as follows to-wit:
BEGINNING at five chestnuts and white oak his corner and with Page's line

[illegible] poles crossing the waggon road to two chestnuts leaving said line
[illegible] poles to a white oak on top of a ridge
[illegible] poles to two white oaks by a path
[illegible] poles to a maple and chestnut by a hollow [illegible] corner to his own land and with the same
[illegible] poles to a maple and sugar tree
[illegible] poles to a sugar tree and locust
[illegible] poles crossing a deep hollow to two white oaks and spanish oak
[illegible] poles to the beginning with its appurtenances.

Figure 4. Example of a Plot Boundary from 1843

We performed a spatial join in ArcGIS, then determined the landform of each corner. Landform data came from an MNF ecological classification system that was assigned during soil surveys. Landforms include ridge, saddle, shoulder, knob, bench, plateau, foothill, toe slope, gentle side slope, middle/back slope, steep side slope, cliff, cove, floodplain, newer terrace, older terrace, valley floor, flat, and valley. ArcGIS Spatial Analyst was also used to model and compare the soil-derived landforms to elevation-derived landforms.

The resultant frequency counts of species by landforms (by subsection) were analyzed for significance through contingency table analysis and chi-square likelihood ratio tests. Standardized residuals were calculated for each landform and species by subsection. The analysis was made on 15,591 corners representing 22,107 witness trees from deeds ranging from 1752 to 1900. Of the database, 24 percent of the corners date to the late 1700s. The greatest numbers of corners were established in the 1840s and 1850s at 17.8 percent and 29.3 percent, respectively.

Findings

Pre-European settlement ridge and valley forests were dominated by mixed oak, pine, American chestnut, and hickories on ridges, while the valley floors were dominated by white oak, sugar maple, pine, basswood, and hemlock. As compared to European settlement-era forests, current forests have less American chestnut, pine, and white oak and greater amounts of chestnut oak, northern red oak, scarlet oak, and red maple in the Ridge and Valley Province and greater amounts of black cherry, red maple, and birch in the Allegheny Mountains province. Many of our findings supported those also found by Abrams and McCay (1996), while our study used more landforms and subsections.

Witness trees provide a glimpse into historical forest conditions for much of the eastern United States due to impacts of early settlement by Europeans and a history of near-complete forest clearing in many states at the turn of the nineteenth century. Because these descriptions represent a static point in time, they should not be considered the restoration endpoint or management goal. However, they are often the best source of information for the time of European settlement, offer clues to Native American influences (or absence of influences) on the landscape, and can inform restoration actions.

Work cited: Abrams, M. D., and D. M. McCay, 1996. Vegetation-site relationships of witness trees (1780–1856) in the presettlement forests of eastern West Virginia. *Canadian Journal of Forest Research* 26: 217–224.

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