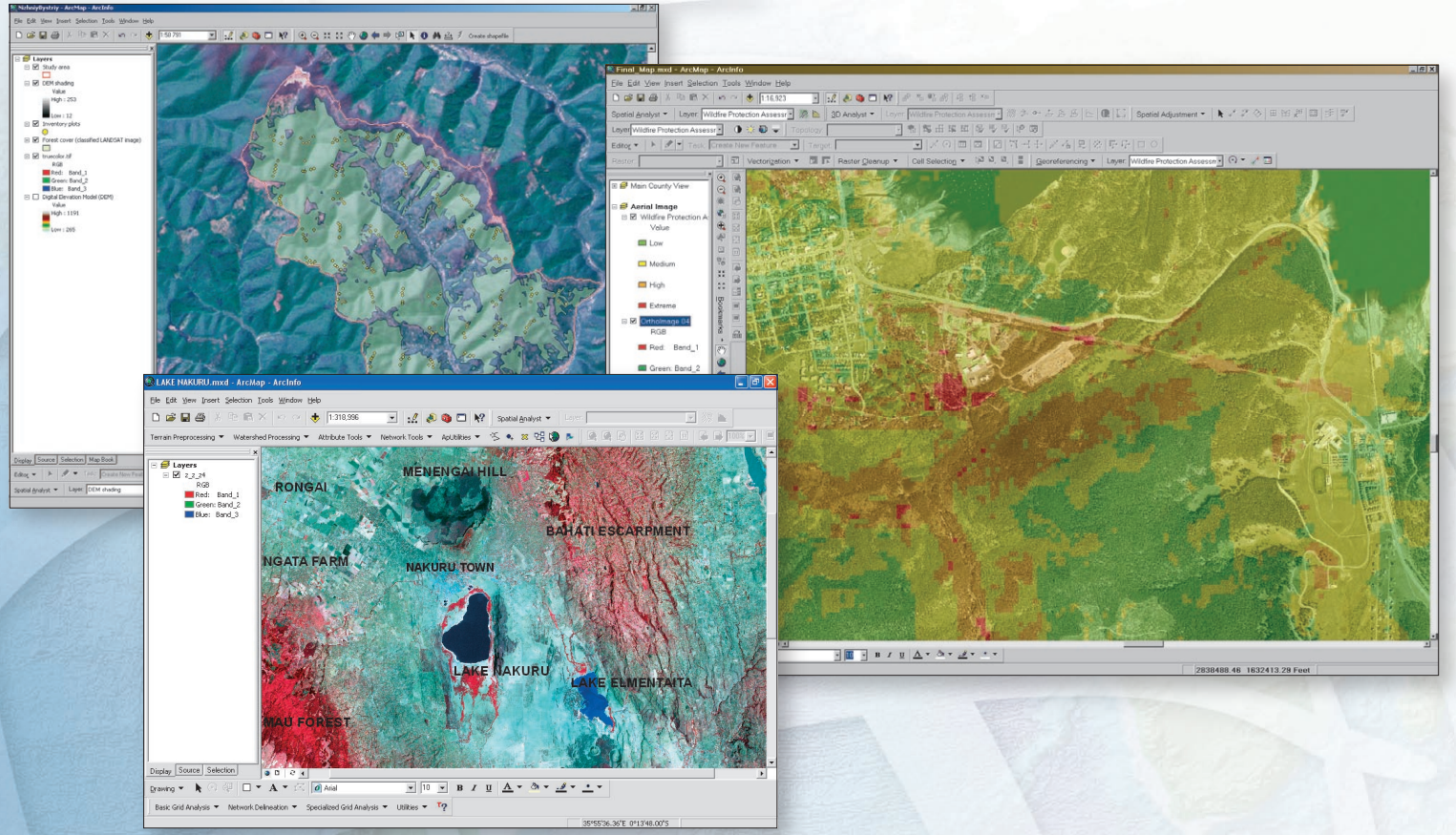
GIS Best Practices

Forest Assessment



August 2006

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

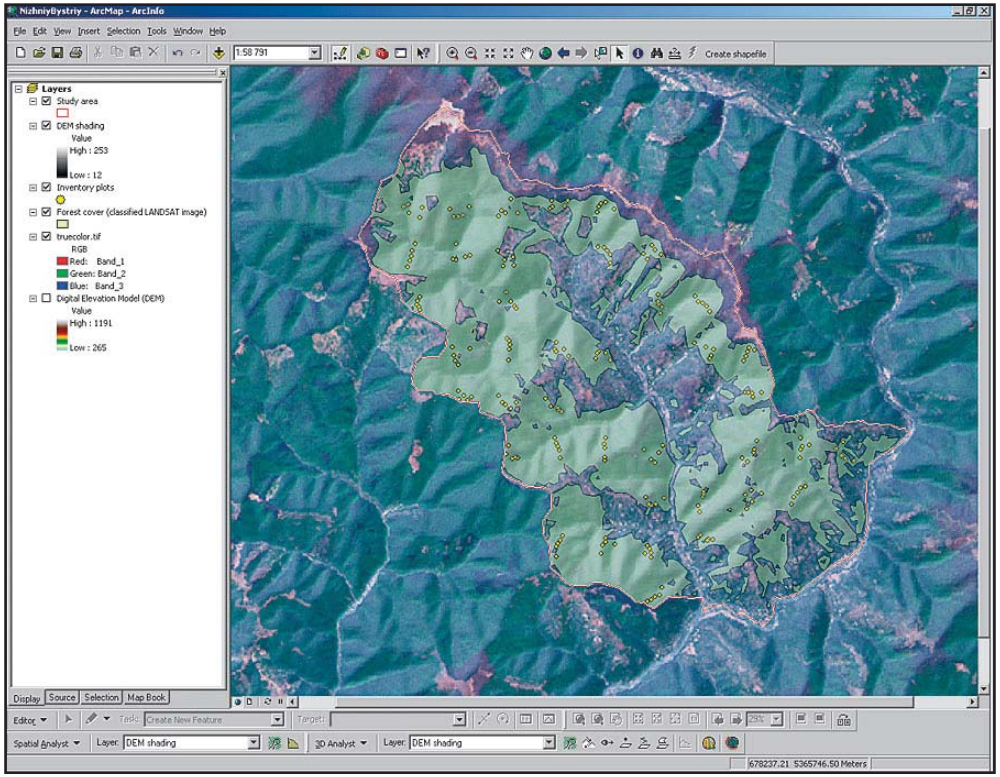
GIS for Forest Assessment

Effective forest managers monitor changing conditions and make intelligent decisions for sustainable care. GIS can be used to assess conditions through historical analysis, stand inventory, soil types, changing weather patterns, and land-use practices. Modeling enables users to test and consider options in both temporal and spatial contexts. Geospatial records provide forest managers with a baseline for evaluating plans.

ESRI offers an array of tools to assist forestry professionals with data management, analysis, decision-making, and monitoring. Applications and extensions offer managers options for the use and management of spatial data on mobile devices, internal networks, and Web-based systems.

In Transcarpathia, Ukraine, GIS Aids Statistical Forest Inventory

By Petr Vopenka and Martin Cerny, Institute of Forest Ecosystem Research



GIS helped to prepare base data for the statistical forest inventory and to design the network of inventory plots.

Transcarpathia, the southwest region of the Ukraine, stretches south of the Carpathian mountain ridge, north of the Romanian border, and east of Slovakia. The majority of the population lives in narrow lowlands in the south of the region along the Tisa River. This includes the Nizhniy Bystriy municipality and watershed, about 60 kilometers north of the regional center of Khust. Despite the fact that the mountains to the north of this region contain enormous amounts of natural

resources, which can potentially be used to raise the living conditions of local inhabitants, many people from Nizhniy Bystriy travel annually to western European countries or to Russia for seasonal work. This is because local businesses and infrastructure are not sufficiently developed to tackle the area's high unemployment rate.

To address this concern, the Swiss-Ukrainian Forest Development Project (FORZA) helped establish principles for well-functioning rural communities by designing the Watershed Development Plan (WDP). Part of WDP is the Statistical Forest Inventory (SFI) that assesses the potential of natural resources in a watershed. In July 2005, to determine whether the mountains contained enough quality timber to help grow the area's economy, an inventory was carried out by the Institute of Forest Ecosystem Research, Ltd. (IFER), in the 5,685 ha Nizhniy Bystriy watershed. IFER is an independent forest research institute located in Jilove u Prahy, the Czech Republic.

Inventory data sent from measuring devices such as a laser range finder and inclinometer, compass, and GPS are organized in a field computer.

As a first step toward designing the network of SFI plots, IFER used global Internet GIS data sources to obtain data needed to define the watershed and estimate the forest cover.

Technology Selection

IFER used ArcInfo and IFER's FieldMap, a forestry application based on MapObjects, to create the SFI in Nizhniy Bystriy. The Khust forest enterprise, which is responsible for the Nizhniy Bystriy watershed, is equipped with an ArcGIS workstation, allowing data gathered before or during SFI fieldwork to be used later by forest managers for further analysis and database building. In addition, each field team was equipped with a laser range finder, an inclinometer, and a GPS and electronic compass mounted on a monopod and connected to the field computer running data collection software.

Because IFER had to respect financial and time constraints of WDP, the fieldwork took 20 working days by two field teams.

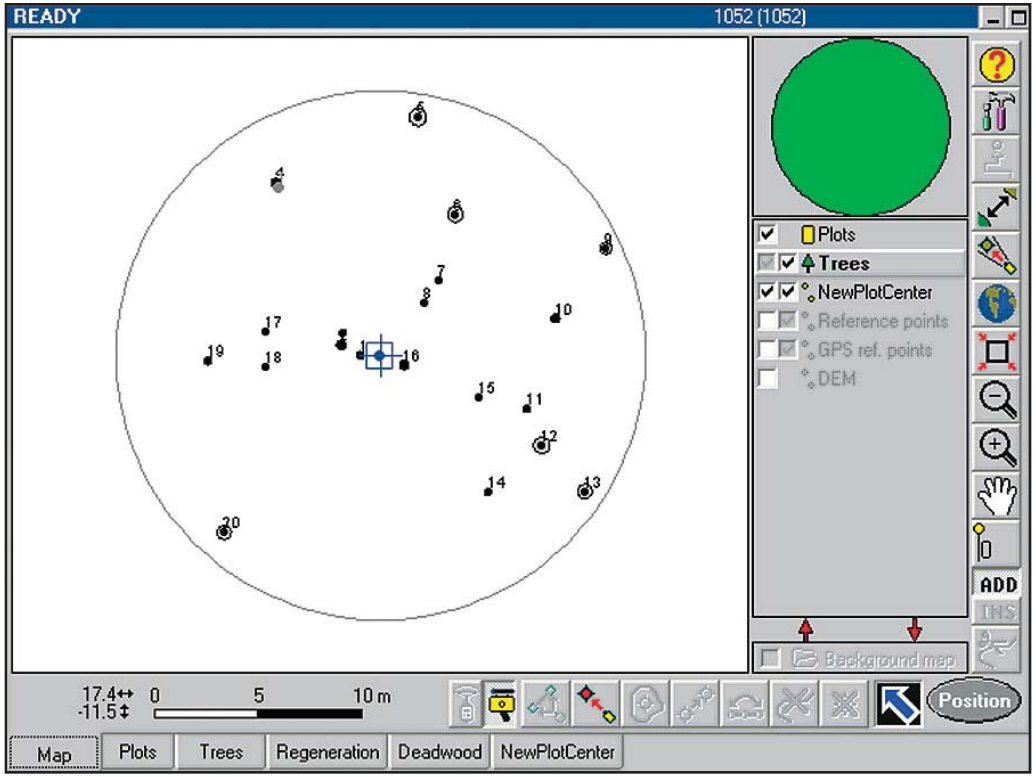
Methods

IFER created the border of the watershed from a Shuttle Radar Topography Mission digital elevation model (DEM) using the hydrological functions of ArcInfo. The forest area was derived from Landsat satellite imagery. They classified the imagery by combining supervised and unsupervised classification methods with ArcInfo. Using these methods, it was possible to get basic information about the study area even before coming to the Ukraine.

IFER performed the SFI measurements on a large number of relatively small inventory plots. The network of SFI plots was designed to representatively cover the area, but at the same time, the plots needed to be accessed with minimal time loss. They used ARC Macro Language (AML) script to create a network of SFI plots using ArcInfo. Plots were grouped in clusters of five, and these clusters, which covered local altitude gradient, were equally distributed in the forested area of the watershed. Each cluster represented one day of work for one field team.

Results

IFER visited 200 plots during the field campaign, subjecting 2,249 trees to detailed biometrical measurements. Using field map technology, they stored the field team data in shapefiles directly in the field. Thus, the office work was reduced to downloading the data and recharging the batteries.



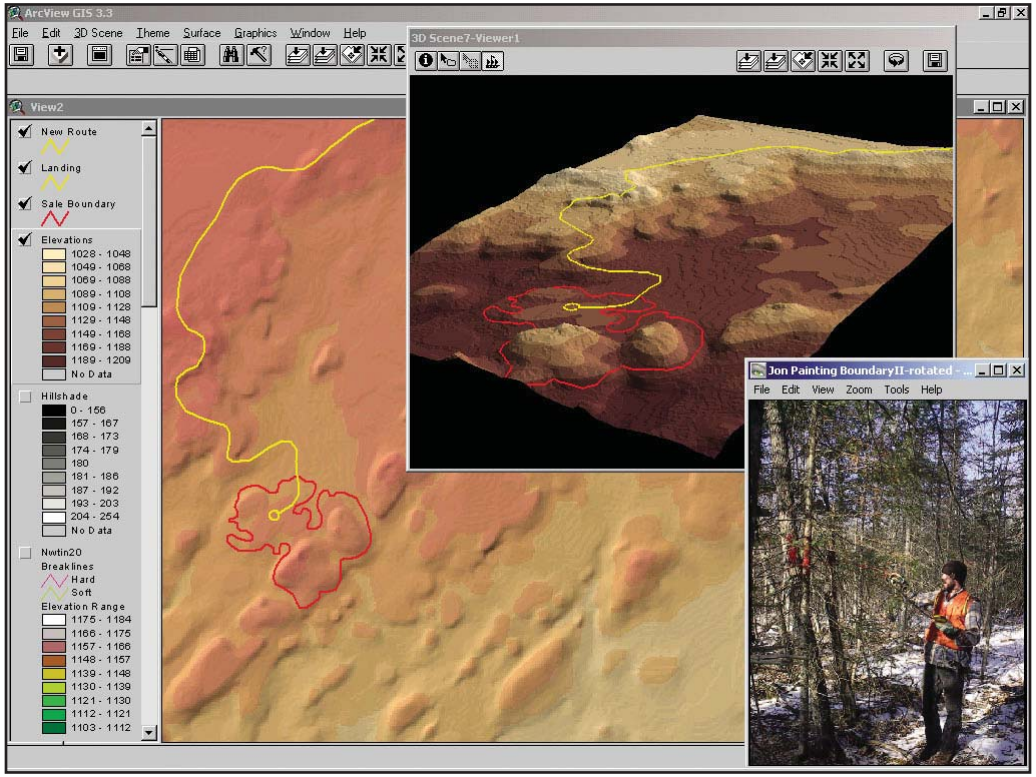
GIS-based application FieldMap has been designed for data collection on sample plots.

Because SFI in Nizhniy Bystriy was focused on standing timber assessment, the main outputs are the timber volume estimations. The results showed that, although the majority of the watershed (87 percent) is covered by mature beech forest with a timber volume of 366 m^3/ha, there are only 35 m^3/ha of quality timber, and as such, the area has limited potential for timber production. This might be bad news for those who hoped for high potential of the forest regarding timber production, but the information is highly valuable for future watershed management planning.

The SFI in Nizhniy Bystriy was funded jointly by the Czech-Ukrainian development cooperation project TechInLes and by the Swiss-Ukrainian development cooperation project FORZA.

(Reprinted from the Winter 2005/2006 issue of *ArcNews* magazine.)

For Douglas County Forestry in Wisconsin, GIS Is the Primary Tool



During sale preparation activities, foresters use GIS to identify specific watersheds, allowing for proper planning and better decision making. Photo inset: Using a GeoExplorer III GPS unit to collect field data while painting in a sale boundary.

Douglas County, Wisconsin, located in the extreme northwestern corner of the state, is rich in unique ecological and biological resources. The Douglas County Forest originated in the late 1920s when the county obtained a large acreage through tax delinquency. Logged over and ravaged by fires, these “unwanted” lands presented no prospect for immediate financial returns and became an increasing burden for the County. Passed by the Wisconsin State Legislature in 1927, the County Forest Law prepared the way and provided the means for the local

establishment of a county forest. The first entry of lands under the Forest Crop Law took place in 1931, consisting of 9,002 acres. Today, the Douglas County Forest is the largest county forest in the state of Wisconsin and fourth largest in the nation, totaling 270,000 acres. The Douglas County Forestry Department is responsible for managing the forest's timber, water, wildlife, and recreational resources.

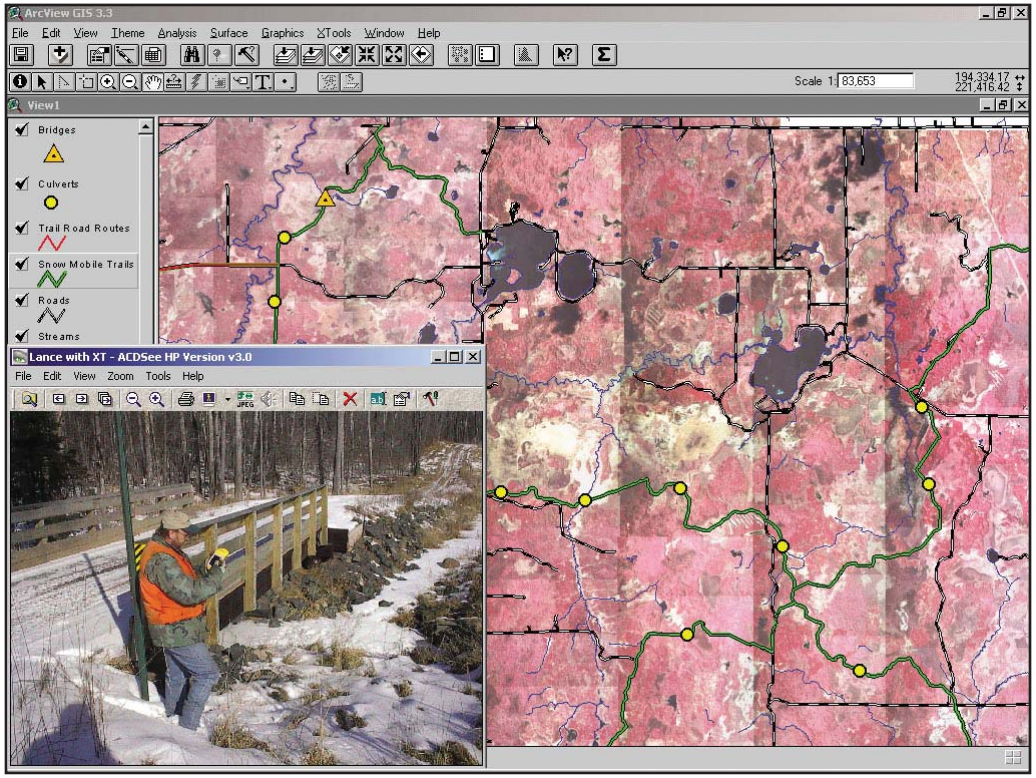
Over the past four years, GIS has proved itself as the primary tool used by forestry staff to analyze and manage Douglas County's natural resources. Since its implementation, GIS has been utilized in many different capacities of the county's natural resource management program including, but not limited to, timber sale establishment, vegetative mapping, watershed and wetland delineation, forest road design and maintenance, sustainable harvest planning and management, wildlife habitat improvement, recreational trail mapping and monitoring, endangered species management, and forest reconnaissance (forest recon) data management. Forest reconnaissance is a tool utilized by foresters and forest managers to assess the geographical, structural, and compositional attributes of the landscape.

Planning for Sustainability

Douglas County was faced with a growing number of pressures, both economically and ecologically, for forest sustainability. New technologies were needed to better manage forest recon data seamlessly without delays due to updating. Since forest recon data is very dynamic and easily influenced by a variety of unpredictable natural processes, a streamlined system was needed that could easily handle instantaneous changes to the data while having a scaled-back architecture suitable for nontechnical end users.

To find an appropriate solution, Douglas County turned to the Wisconsin Department of Natural Resources (WI DNR). Created in 1999 by the WI DNR Bureau of Forestry, a fully integrated forest recon management tool code-named RAVE (Recon ArcView Editor) was implemented. The software was developed primarily in an ArcView 3.x environment around an Avenue script core. Statewide tabular forest recon data for both state and county forests resides in an Oracle database. Maps and reports are generated in ArcView and produced by Crystal Reports. RAVE provides users with tools for addressing fundamental forest inventory updating, harvest planning, silvicultural prescriptions, reforestation activities, and stand maintenance scheduling. The application runs locally at county and state forestry offices with locally stored data being continuously uploaded into the central Oracle server.

“RAVE has become an essential tool in managing our day-to-day forest activities,” says Jim Latvala, forester for Douglas County. “Its user-friendliness allows foresters to become more accountable for updating data and planning management activities.”



Douglas County snowmobile trails, road routes, and bridge locations. Photo inset: Using ArcPad on a Trimble GeoXT to update trail route changes and new bridge locations.

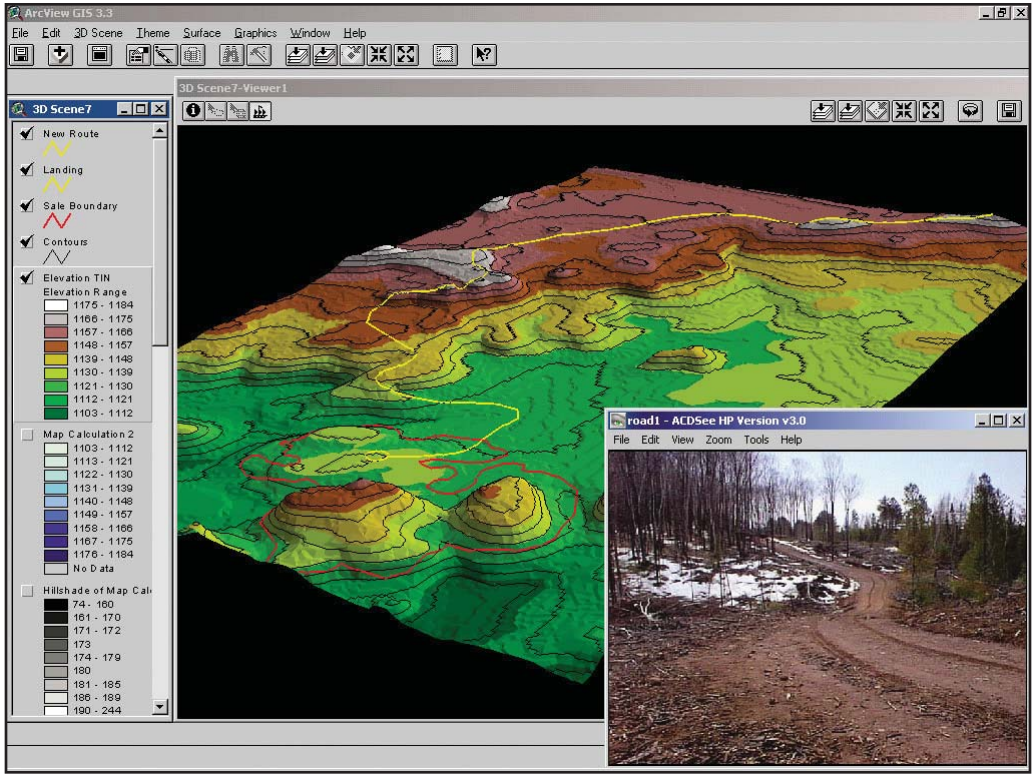
Striving for sustainable forest management, the instantaneous forest recon updating provided by RAVE allows for more accurate data to be incorporated into commercial timber growth models as well as annual allowable harvest calculations. With the responsibility of planning and managing approximately 3,500 acres of allowable cut and scheduling silvicultural prescriptions and reforestation activities over 269,850 acres, Douglas County has implemented a fully functional, user-friendly, integrated GIS.

Forest Structure Management

The primary management activity performed by Douglas County forestry staff is the establishment of commercial timber sales. Stands of aspen, white birch, red oak, northern hardwoods, and jack pine are under intensive even-aged forest management practices. Historically, many of these species were overharvested in a short time period resulting in poor age-class distribution over the current landscape, leading to reduced horizontal structural diversity throughout the forest. A multistoried or structured landscape provides many benefits to wildlife, forest health, species composition, human aesthetics, and overall ecological diversity. By incorporating remotely sensed land cover and forest recon stand height data into an ArcView project utilizing the ArcView 3D Analyst extension, large blocks of undisturbed, mature timber with very little structural diversity are easily visually identified and prioritized for possible sale establishment locations. Compared to simple two-dimensional coverages, modeling horizontal forest structure in three dimensions has provided a much better visual graphic for foresters to use as a tool in planning management efforts as well as examining effects of past practices.

Timber Sale Establishment Planning Process

Timber sale establishment is the process of locating, analyzing, establishing, and preparing a particular stand of timber for harvesting. Traditionally, foresters relied on black-and-white 1:15,840 aerial photography and acetate film for hand-drawn maps to estimate locations, road routes, boundaries, and acreages of timber sale preparation activities. These estimates were often inaccurate and resulted in significant errors. Facing growing pressures from the logging industry and a drive for improved product quality, three Trimble GPS GeoExplorer III units were implemented in many phases of the field data collection activities. Area, line, and point features, such as boundaries, proposed road routes, parcel corners, and survey monuments, are recorded in the field and later incorporated into ArcView where topography, black-and-white/ infrared digital orthophotos, and watershed hydrology coverages are used to further analyze timber sale establishment planning activities. United States Geological Survey 10-meter digital elevation models (DEMs) are imported into ArcView, and ArcView Spatial Analyst is used for topographical analysis such as calculating the total topographical surface area of specific forest stands, crucial to accurately estimating wood volumes. Subsequently, DEMs are viewed three-dimensionally with ArcView 3D Analyst, allowing for better planning and designing of sale boundaries and new timber access road routes.



The planning and proper construction of a new 3.5-mile road through a remote area was accomplished with ArcView, Spatial Analyst, and 3D Analyst. Photo inset: Actual road upon completion.

Managing Recreational Resources

Faced with the challenge of developing and maintaining 300 miles of snowmobile and seasonal all terrain vehicle trails, 17 miles of cross-country ski trails, and numerous nature-hiking trails, Douglas County once again turned to GIS for a solution to more efficiently and effectively manage complex trail maintenance and monitoring data. Mapping the countywide trail system was accomplished with GPS technology where ArcView software's geoprocessing and feature editing tools were used for further analysis and manipulation of data. Attributes, such as trail names, types, permitted uses, seasonal designations, and property owners, were attached to trail features. In addition to simplifying logistics, the use of ArcView by recreational staff has proved itself a real time-saver in scheduling, mapping, and monitoring general maintenance activities such as trail grading and grooming. Recently, the department has continued to

streamline and expand this program by implementing ESRI's ArcPad, a mobile GIS on a Trimble GeoXT GPS platform, incorporating trail gate, culvert, and bridge monitoring data.

(Reprinted from the Summer 2003 issue of *ArcNews* magazine.)

Beetles Destroy Forest

SCE Maps Vegetation Mortality

The San Bernardino National Forest is experiencing significant drought-related vegetation mortality. Forests in the mountainous regions of San Bernardino, Riverside, and San Diego Counties of California are dead or dying due to the widespread infestation of the bark beetle.

More than 100 years of fire suppression have resulted in overly dense stands of trees. This, followed by a five-year drought, has resulted in too many trees competing for too little moisture. As a result, the trees are highly susceptible to bark beetle attack. These beetles are now at epidemic proportions.

Approximately 400,000 acres of trees in the San Bernardino and San Jacinto Mountains on both private and public lands are dead or dying. The California Department of Forestry and Fire Protection (CDF) estimates that 900,000 trees have already died. The number of dead trees will continue as the bark beetle infestation spreads. About 100,000 people live within these mountains. If a large fire occurs, it is likely to threaten the lives of many residents and forest visitors. According to the San Bernardino and Riverside County Tax Assessors, residential and commercial properties in the national forest area mountain communities have a combined assessed value of more than $8 billion.

On March 7, 2003, a California executive order proclaimed a state of emergency in San Bernardino, Riverside, and San Diego Counties in response to the bark beetle infestation. On April 3, 2003, the California Public Utilities Commission (CPUC) directed Southern California Edison (SCE) and other utilities in the affected counties to take all reasonable and necessary actions to remove trees threatening power lines.

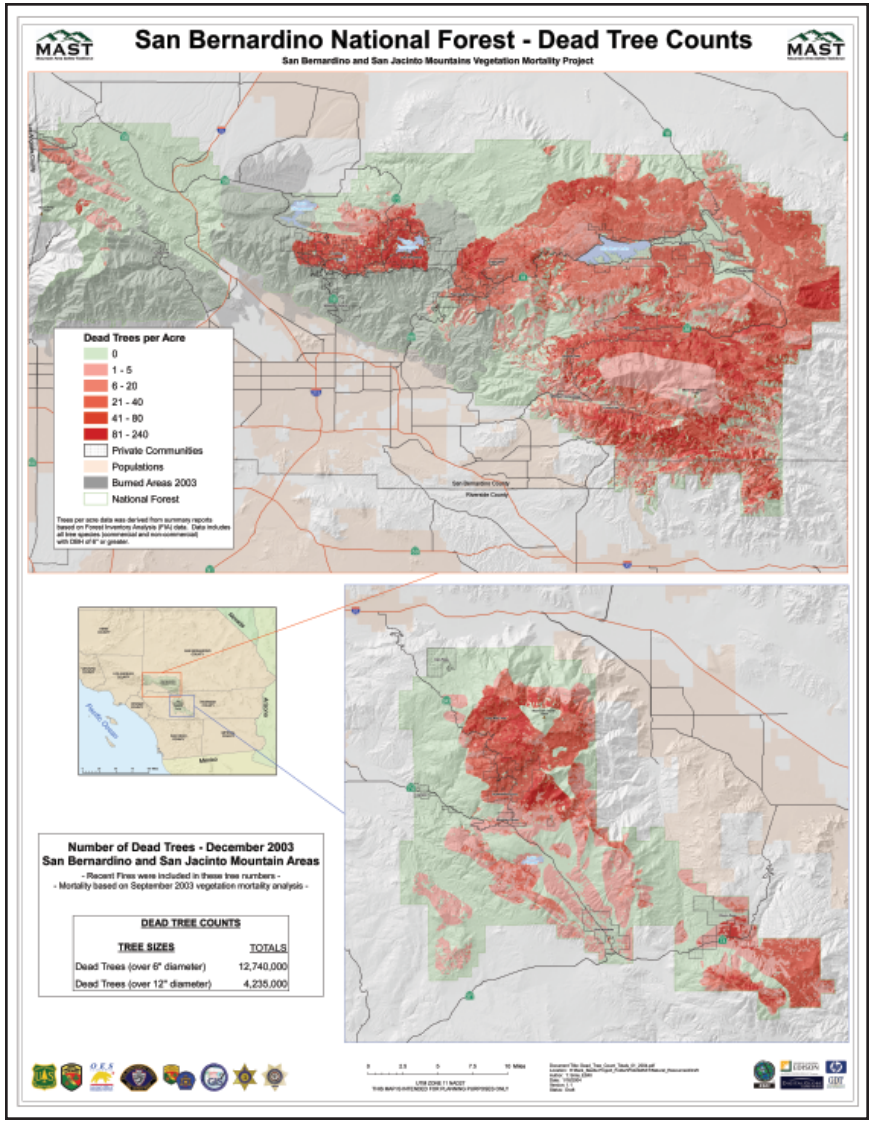


Figure 1. This map represents dying trees in the San Bernardino National Forest, an important factor in the rapid spread of recent fires. The percentage of dead trees in the area (represented by reds) is greater than living trees (greens).

In response to the state proclamation and CPUC's directive, SCE is working in conjunction with CDF and county, state, and federal officials to remove hundreds of thousands of trees in the affected regions.

ESRI, in collaboration with resource management experts and SCE, helps provide a priority model to determine treatment areas and prioritize them based on variables such as vegetation mortality, population, roads, utilities, and other values.

A careful watch is being kept on the forest's high fire risk areas by these agencies and many others. The Mountain Area Safety Taskforce (MAST) is central to coordinating this effort. It sponsors a public service information program. Its Web site, supported by ArcIMS, delivers interactive map updates about fires, vegetation mortality, and other valuable public safety information (Figure 1).

"We perform analysis to fully understand the extent of the dead and dying trees and all the drought-related problems existing in our local forests," says Gerco Hoogeweg, MAST project manager for the lab. "We also want to get an accurate understanding of the progression of the problem that is taking place. This was used for the recent wildfires, and we will continue to refine the database to respond to possible future events."

SCE, along with federal, state, and local agencies, is part of a large-scale effort to remove the infested trees, which will take five years or more to complete. SCE is cataloging dead or dying trees near its power lines. At the same time, it is removing trees, beginning with those that are in the greatest danger of downing electrical lines. SCE's tree removal schedule for residents, businesses, and property owners in the affected areas is posted on MAST's Web site (Figure 2).

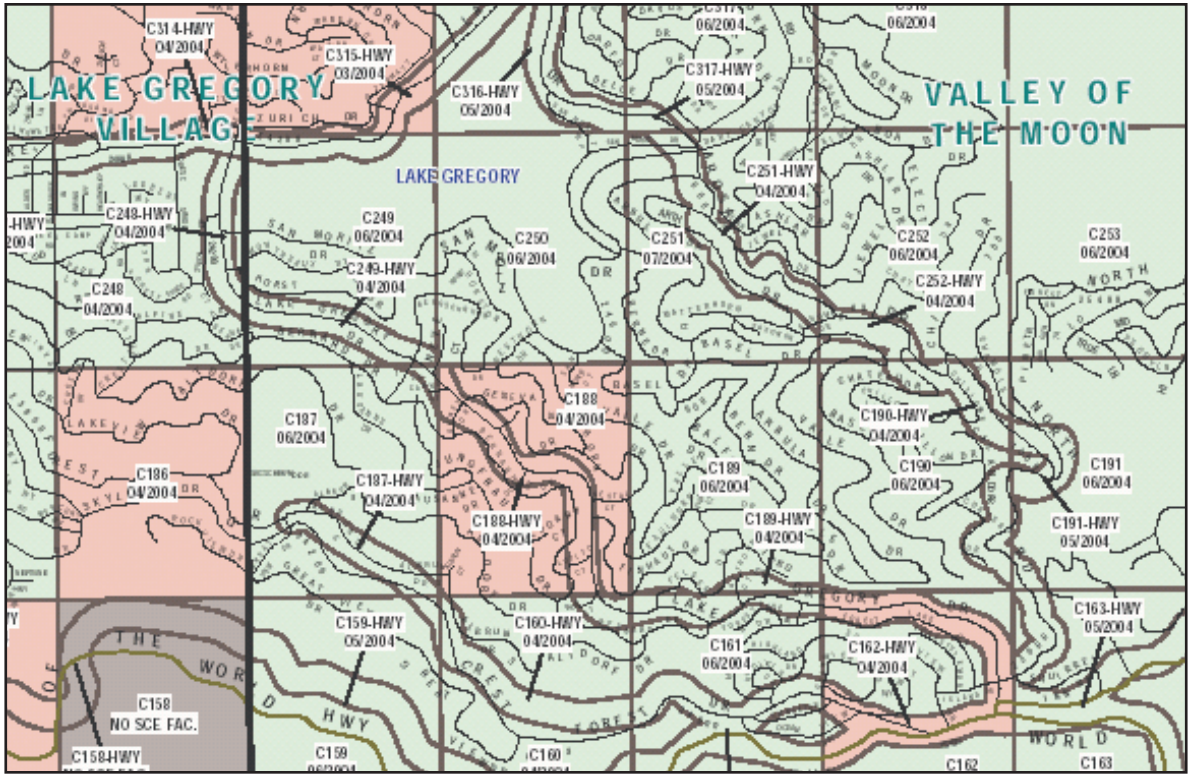


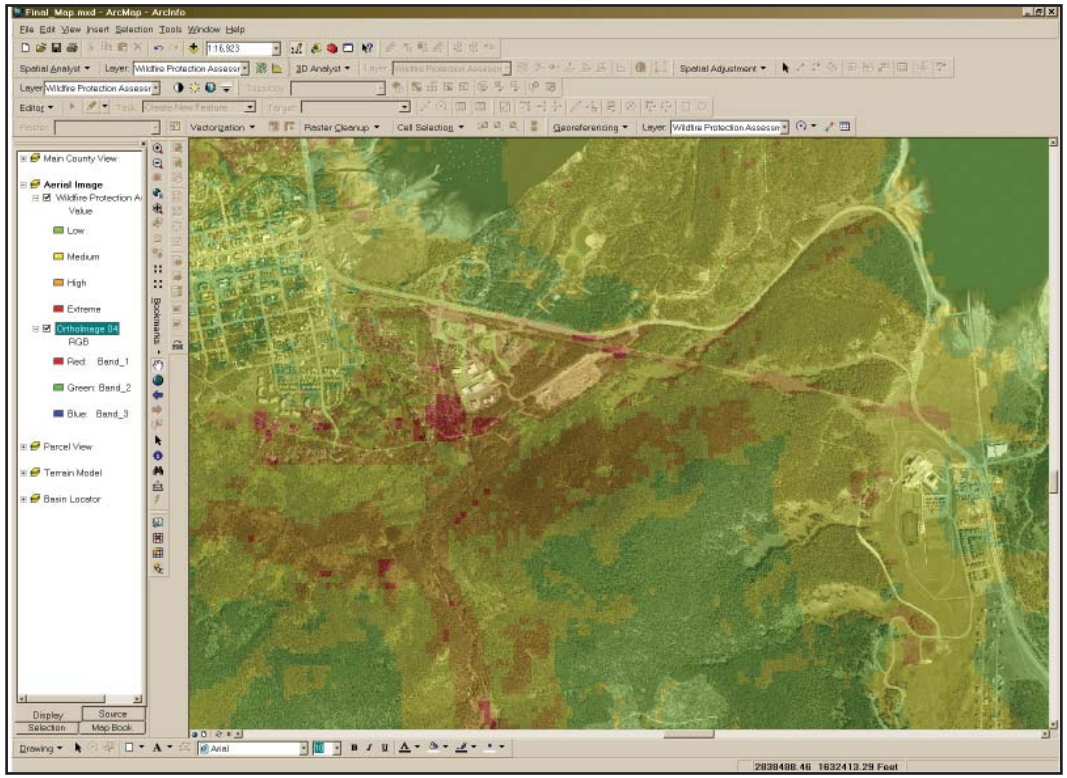
Figure 2.

As work in specific areas is scheduled, electric power to nearby homes may need to be temporarily cut off—in extreme cases for up to 24 hours. SCE notifies residents of scheduled tree removal and outages before work begins so they can prepare appropriately for after-dark lighting and perishable food storage needs. The MAST Web site linked to the SCE Web site is an important up-to-date resource for the community to see the state of the forest.

(Reprinted from the Fall 2004 issue of *Energy Currents* newsletter.)

County Uses GIS for Community Wildfire Protection Plan Risk Assessment

Summit County, Colorado, developed a Community Wildfire Protection Plan (CWPP) to address issues of wildfire response, hazard mitigation, community preparedness, and structure protection. ArcGIS was central to this project for managing data, computing values, depicting at-risk areas, creating correlations, and performing many other essential functions necessary to devising the plan.



GIS analysis proved its worth—a wildfire broke out within the area analysts had assessed as having high risk for wildfire (indicated in red for high value).

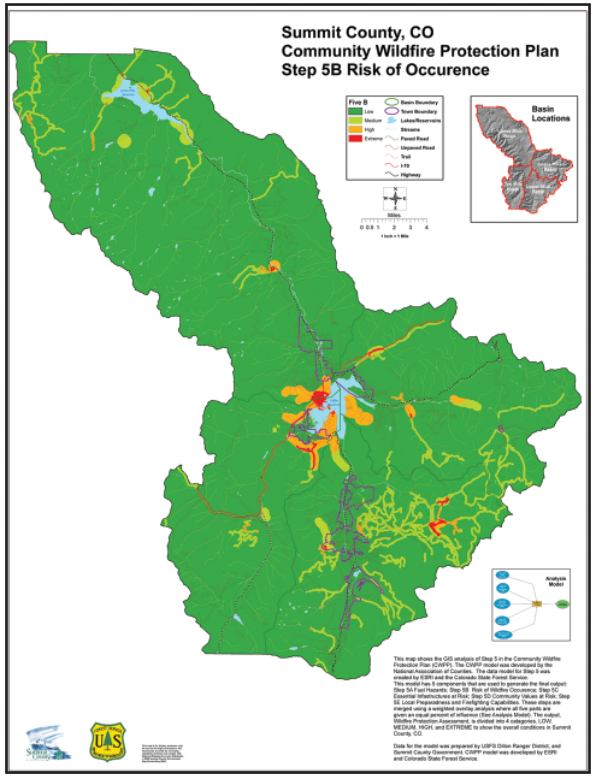
Summit County needed to include in its CWPP the best applications of financial and physical resources and support the county's communities with a proactive fire mitigation program. To create a plan, data must be organized and processed in a way that is usable to a variety of people. Map outputs were needed to provide a clear foundation for discussion and be easy to revise to accommodate community input.

Fire risk assessment models created with GIS are tools that can be used as a guide for focusing fire mitigation and response resources. These models are used to create themes such as fire history, vegetation, slope, and aspect. A weighting system is used to determine which areas are most prone to extreme fire behavior. Summit County worked with ESRI and the Colorado State Forest Service to develop its risk model. Fortunately, the Colorado State Forest Service had already prepared an application built using the ModelBuilder application within ArcGIS Desktop that contained components that would produce the essential protection assessment for an area. The application had already been successfully used in Teller County, Colorado. The team decided on the objectives of the project and the models and level of data needed to meet those objectives. ArcSDE was used to manage the complexities of the database.

The Colorado State Forest Service recommended a general five-step work plan for creating the Summit County CWPP: The first step is to convene decision makers; second, involve federal agencies; third, engage interested parties; fourth, establish a community basemap; and fifth, develop a community risk assessment. GIS was used in each of these steps and extensively relied on to provide products for risk assessment analysis.

Risk assessment data used for developing the county's CWPP is composed of a matrix of fire-related components. The fuel hazards data layer includes the rate of spread, heat per unit of area, length of flame, and so forth. Another layer is used to assess the risk of fire occurrence, which includes historical fire information and factors attributed to starting fires such as lightning strikes, campgrounds, dispersed camping, and back country roads. Central infrastructure information is also an important consideration. This data category includes homes and businesses, which are represented by dot density and cluster maps. Critical businesses and business corridors were also highlighted. Communication towers vital to emergency services and network information and power lines were listed as crucial. Other significant infrastructures at risk are watersheds and pump stations. Major escape routes are protection points because they are vital for getting people out of subdivisions and the county to safe places. GIS computed a weighted overlay, which it then spatially represented to indicate critical infrastructure locations.

Another layer in the data model is community values at risk. Summit County's large open spaces have few structures and, consequently, have been assigned a lesser value rating than subdivision areas. Subdivision values from high to low were provided by the county's building department. Also, habitats for endangered species were attributed with a high value. Open spaces did not receive high response values because fire is considered advantageous to the health of the ecosystem.



Risk of occurrence data includes factors attributed to starting a fire. These are weighted to depict the levels of fire risk for an area.

Finally, an information layer for local preparedness assessment was included. It addressed the county's capacity, such as fire stations and water access, to fight certain types and sizes of fire. This layer includes fire station sites, hydrant and cistern locations, cost-distance analysis on

roads and slopes, and water resources for helicopter and plane water pickup points for drops. Assessments were made about the accessibility to fires in extreme conditions and if certain locations were too steep, too far away, or too inaccessible to protect. It indicated at-risk fire areas that would create dangerous circumstances because of dead-end roads and no escape routes.

Once the data was gathered and the model designed, ESRI's ArcGIS 9.1 software was used for creating different types of maps and analyzing details. The GIS analyst used ArcGIS Spatial Analyst and ArcGIS 3D Analyst to make correlations and create spatial representations. Data was entered into ArcScene to show how features lie along ridgelines.

Initially, weights were assigned and overlays were created for each of these analysis components and used as a starting point for dialogue. People who knew the areas reviewed the maps and added their edits and concerns. In addition, planning commissioners, local planning department and county planning department staff, fire authorities from the county's different fire districts, and wildland fire crews were invited to participate in reviewing the maps and adding to the development of the plan. Based on this collective information, weights were revised. GIS recalculated the variables to create a foundation for a document that was indeed a community plan.

Trip McLaughlin, Summit County's GIS analyst, worked diligently to make the project a success. He says, "This project was just plain fun. We took a model ESRI had developed as a general basis for the project. We plugged our data into the model, and everything worked. We were able to get good cooperation from a variety of people who provided the data sources. People worked together on this project from GIS users to field-workers. People were able to understand the project and the maps. They were glad to give their input and get fast GIS feedback. People were pleased to be able to put the maps to work. Their involvement added a lot of weight and merit to what GIS was doing for the county."

PDF file images and printed maps are shared with community agencies such as homeowners associations, insurance providers, forest service maintenance crews, and others.

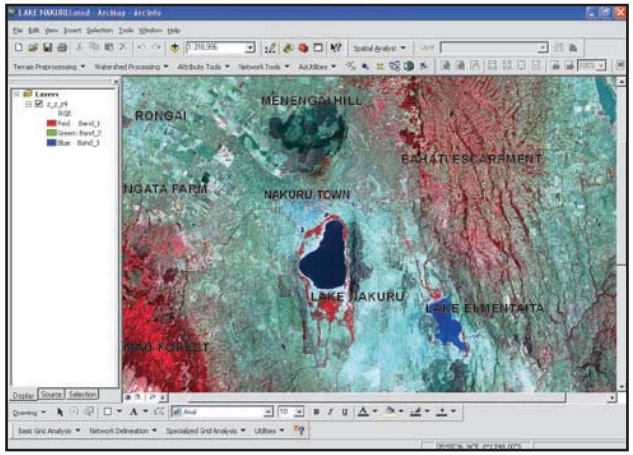
Summit County's GIS is serving to prove the case for the plan. Shortly following the development of the risk map, a fire broke out in an area that the new plan had designated as extreme for fire. The real-world event met the analyst's prediction, giving credence to the effectiveness of the analysis.

For tips on developing a CWPP for your community, see an online copy of the handbook Preparing a Community Wildfire Protection Plan at www.safnet.org/policyandpress/cwpphandbook.pdf.

(Reprinted from the Winter 2006 issue of *Environmental Observer* newsletter.)

Kenya Uses GIS for Sustainable Development Planning

Lake Nakuru National Park lies within Kenya's Great Rift Valley. The park is the world-famous habitat for migrating flamingoes and is home to approximately 50 mammal species, 400 bird species, and 300 plant species. The park is an important source of revenue for the Kenya government. Unfortunately, urbanization causing deforestation has strongly impacted the region. Kenya's Egerton University has been employed to develop initiatives for sustainable development in the region for improving livelihoods while supporting environmental rehabilitation. The university is using GIS as an assessment and decision-making tool for this project.



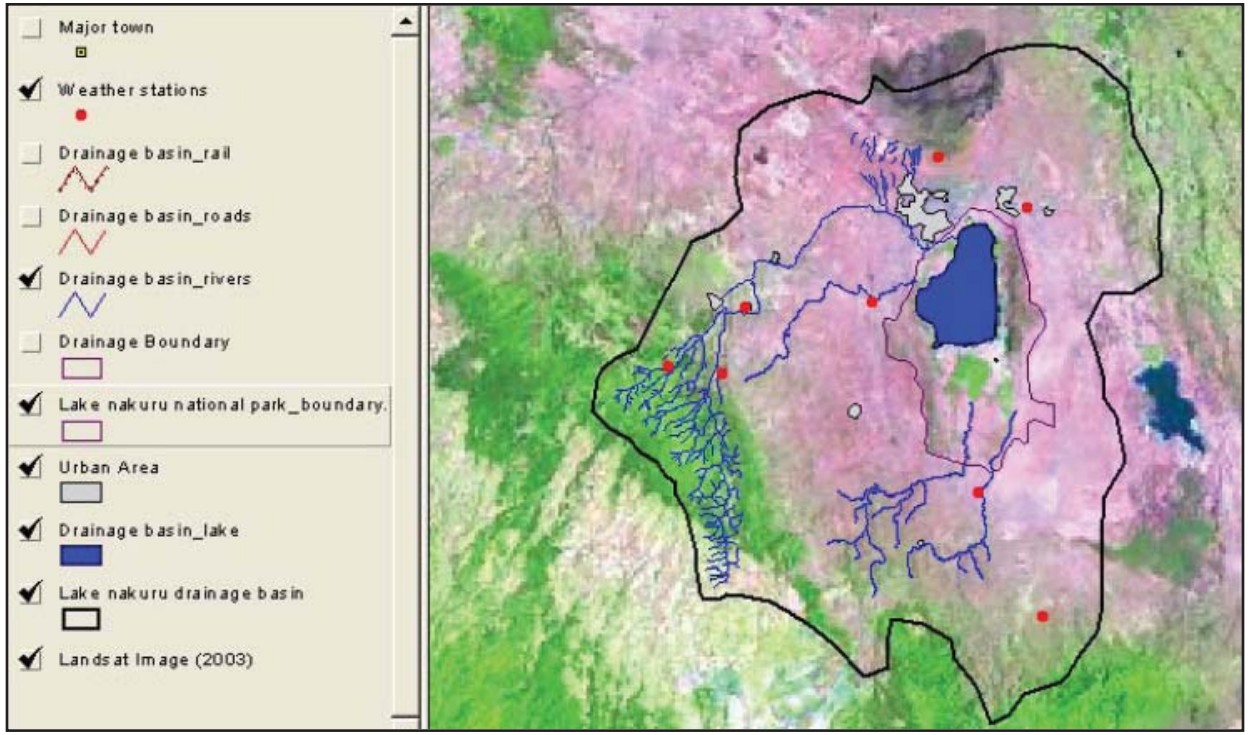
A Landsat image in GIS shows Nakuru Town, Lake Nakuru, Lake Elmentaita, Menengai Hill, and surrounding farms.

The environmental degradation of the region has increased during the last 40 years. The Lake Nakuru basin has transformed from a densely forested area into a region that is heavily settled, extensively cultivated, and rapidly urbanized. Approximately one million people live in the basin including 350,000 in the Nakuru Municipality. Forests within the lake catchment have been cleared at rapid rates and the land converted to farms, homes, towns, and industrial sites to accommodate the expanding population. Today, forest cover has declined to less than 15 percent. More than 45 metric tons of soils are lost annually from every cultivated hectare,

which is five times what the erosion rate would be if the forest was not being removed. This decreases both farm productivity and wildlife stability. A plan must be implemented to develop regulation of the region's pollution sources and support sustainability efforts for the region's population.

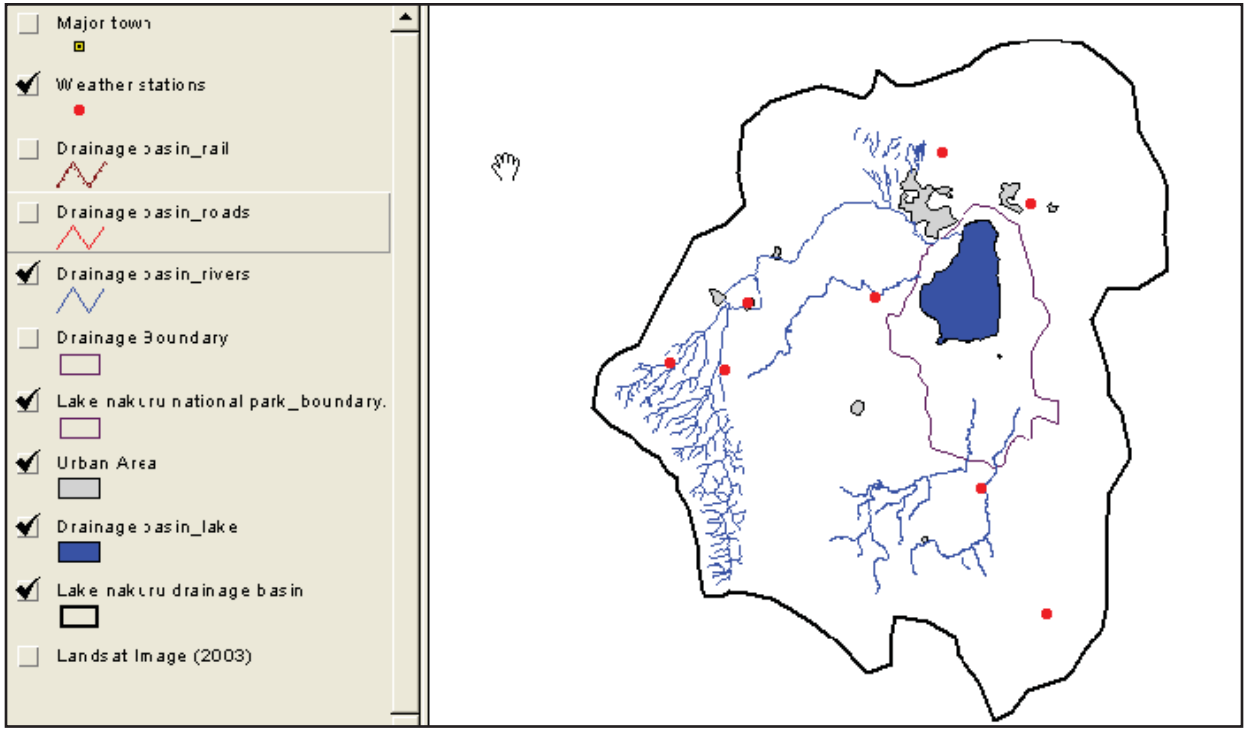
Lake Nakuru is surrounded on all sides by human encroachment. Deforestation, soil erosion, and industrialization are contributing to the environmental degradation of the lake.

In response to these environmental and economic concerns, Egerton University, in collaboration with Kenya Agricultural Research Institute (KARI), is working with a number of stakeholders to reduce the driving forces that threaten the lake's existence and the well-being of the ecosystem as a whole. Using ArcView and ArcGIS 9 software, Egerton University's GIS Center is developing an environmental database and creating applications for analyzing environmental concerns. The GIS Center has designed a cost-efficient method of land-use area estimation that uses free, medium-resolution satellite images downloaded from the U.S. Geological Survey Web site. Analysts use this data in the GIS to estimate land-cover and land-use change, which helps them spatially depict environmental changes for the region at any time.



Lake Nakuru drainage basin and the extent of the national park.

GIS is also being used as a tool for environmental education programs in local communities. These programs emphasize sustainable natural resource management including sustainable agriculture, water and energy conservation, reforestation, and pest management techniques. These skills include soil and water conservation, organic farming, and agroforestry.



Lake Nakuru drainage.

Many surrounding villages are participating in village environmental committees. Participants include farmers, industrialists, women's groups, schools, scientists, extension workers, and government administrators. The university's GIS map products are being made available to these groups to help them develop consensus-based natural resource management plans.

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