GIS Best Practices

Forest Carbon Management

December 2009

ESRI

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What Is GIS?

A geographic information system, or GIS, is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. Or, in simple terms, it's a computer system capable of holding and using data describing places on the earth's surface.

Many computer programs, such as spreadsheets, statistics packages, or drafting packages, can handle simple geographic or spatial data, but this does not necessarily make them a GIS. A true GIS links spatial data with geographic information about a particular feature on the map. For example, the polygon that represents a forest on a map doesn't tell you much about the forest except its location. To find out who owns the forest, the tree species it contains, its health, and what logging activities are planned, you must query the database.

Using the information stored in the database, you could create a display symbolizing forest stands according to the type of information that needs to be shown.

In short, a GIS doesn't hold maps or pictures—it holds a database. The database concept is central to a GIS and is the main difference between a GIS and drafting or computer mapping systems, which can only produce a good graphic output. All contemporary geographic information systems incorporate a database management system.

A GIS gives you the ability to associate information with a feature on a map and create new relationships that can determine the suitability of various sites for protection, sustainable management, reclamation, and so forth.

GIS for Forest Carbon Management

Allowing earth's forests to thrive and do their job of carbon sequestration is essential to reducing the threat of climate change. Technology offers hope to the greenhouse phenomenon caused by industrial society. One such technology is ESRI's ArcGIS, which offers scientists, decision makers, and policy implementers a critical tool for obtaining information they need to heal our planet. GIS allows temporal climate data to be visualized, contrasted, and forecasted. Use ArcGIS to study current land use, land-use change, and what-if scenarios for responsible planning. Turn to ArcGIS for

- Robust imagery management. Handle hundreds or thousands of files. Publish image services that you get directly from your source imagery. Quicken imagery data retrieval and lower bandwidth requirements using the fast access functionality.
- Geospatial metadata. Document how, when, where, and by whom the data was collected; information on its availability and distribution; its projection, scale, resolution, and accuracy; and its reliability.
- Multiple imagery management. Use robust imagery capability formats, projections, and resolution from multiple sources, such as ground truthing data, for assessment that goes beyond satellite imagery.
- Integration with many management systems to broaden analysis solutions.
- Spatial modeling and analysis. Analyze cell-based raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate raster data with traditional vector data sources.
- Spatial data exploration using sophisticated statistical methods. Create a surface from limited data measurements in which extensive data collection is impractical or impossible.
- Infrastructure that supports sharing. Share data across disciplinary boundaries that span the environmental and social science fields. Better analyze the cross-sector studies of a symbiotic relationship between climate change, sustainable development, and the conservation of natural resources.

The robust functionalities provided by ArcGIS help scientists gain a better understanding of the structure and content of geographic information and ensure proper model specification and validation. It also provides governments with methodologies to make decisions and employ solutions for a better world.

Carbon Nation

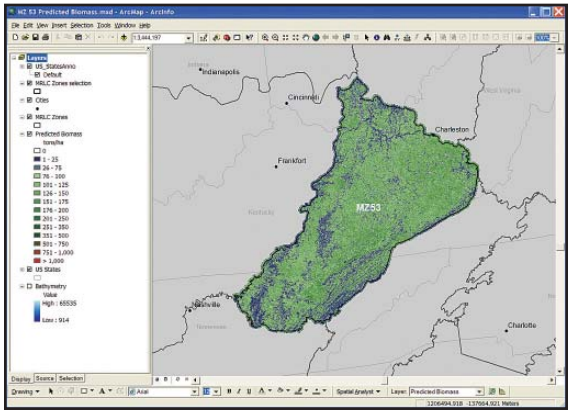
Automated GIS Process Is Creating a Snapshot of Biomass and Carbon in U.S. Forests

By Gregory J. Fiske, Woods Hole Research Center, Falmouth, Massachusetts

Summary

Scientists at the Woods Hole Research Center are using Python to automate processes for use in preparing the National Biomass and Carbon Dataset.

Carbon is a hot topic these days. People everywhere are increasingly aware that carbon in the form of carbon dioxide (CO_2) is one of the greatest contributors to the global climate change problem. Even school-aged children now know about fossil fuels and how our excessive use of them contributes to the accumulation of greenhouse gases in the atmosphere. At the same time, researchers around the world are working to understand where carbon is being stored, how much is being stored over time, and how this information can be used to better understand the global carbon budget. But while coal-fired power plants and SUVs have become icons of carbon imbalance, we tend to overlook another leading contributor to human-induced carbon emissions: land-cover change.



Modeling and prediction activities for NBCD2000 are being carried out using ecoregional zones developed by the Multi-Resolution Land Characteristics Consortium.

The connection between the carbon cycle and land cover is complex. Understanding the role of land-cover change, such as the conversion of forest to pasture or prairie to pavement, is a chief objective of scientists at the Woods Hole Research Center (WHRC), an environmental science, education, and policy institution on Cape Cod in Massachusetts. The center's staff have been pursuing answers to this question for many years, employing tools such as GIS and remote sensing to aid them in determining how much carbon exists, where it is located, and why it matters.

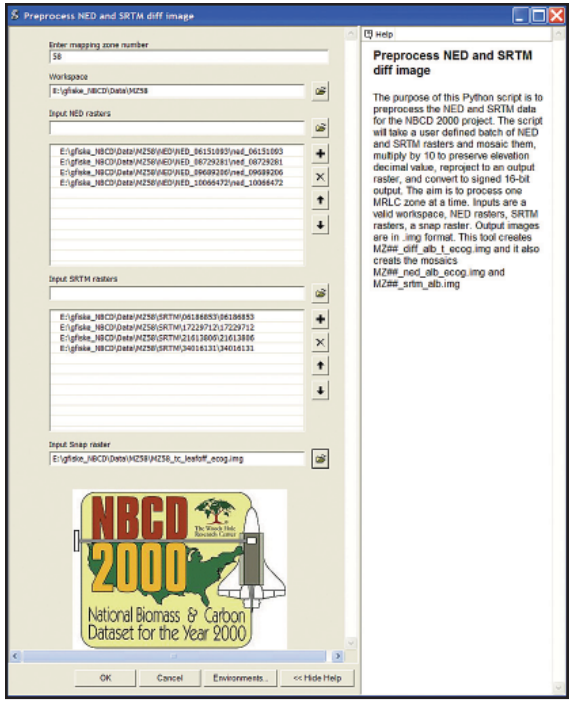
Looking at Biomass and Carbon

A team at WHRC has undertaken an ambitious project to quantify the amount of biomass and, in turn, the amount of carbon that blankets the 48 conterminous United States. Dr. Josef Kellndorfer, an associate scientist at WHRC, and his team are generating the National Biomass and Carbon Dataset for the year 2000 (NBCD2000). This project makes use of high-resolution (30 meter) National Aeronautics and Space Administration (NASA) satellite datasets, topographic survey data, national land-use/land-cover data, and extensive forest inventory data collected by the United States Department of Agriculture Forest Service Forest Inventory and Analysis (FIA) Program.

With this large collection of data layers at a nationwide scale, the challenge is managing data systematically and automating processing tasks wherever possible. Modeling and prediction activities are being carried out using polygons describing the 67 ecoregional zones that were developed by the Multi-Resolution Land Characteristics Consortium (MRLC) as a basis for mapping. *[MRLC (www.mrlc.gov) is a group of federal agencies that joined together to purchase Landset 7 imagery and coordinate production of the National Land Cover Database.]*

Automating Data Preparation

Use of this data required that each of the dozens of GIS procedures employed in data preparation and analyses be repeated 67 or more times. Additional processing resulted from model updates, data modifications, or error fixes. Many data preparation tasks—such as reprojecting, clipping, raster-based math, and associated analyses—were conducted in the desktop environment. To automate these tasks in ArcGIS Desktop 9.2 (ArcInfo), the NBCD2000 team turned to Python scripting. For each task, a Python script was written and linked to a toolbox GUI in ArcToolbox. The collection of scripts was gathered into a single NBCD toolbox and shared with each WHRC team member via a local server running ArcGIS Server 9.2. Kellndorfer felt the development of an automated strategy was crucial for maintaining workflow and continuity from zone to zone because data preparation tasks were divided among the team members.



New NBCD2000 project team members can quickly be productive because the tools in the NBCD toolbox have been completely documented.

The actual statistical modeling of biomass is accomplished using a Linux-based high-performance computing cluster with multiple processing nodes. Both commercial and open-source image processing software was also used for a variety of analysis tasks. The team made every effort to ensure that all software packages worked together smoothly. For ease of integration in subsequent processing steps, Python scripts were written to generate files with the appropriate format and data type.

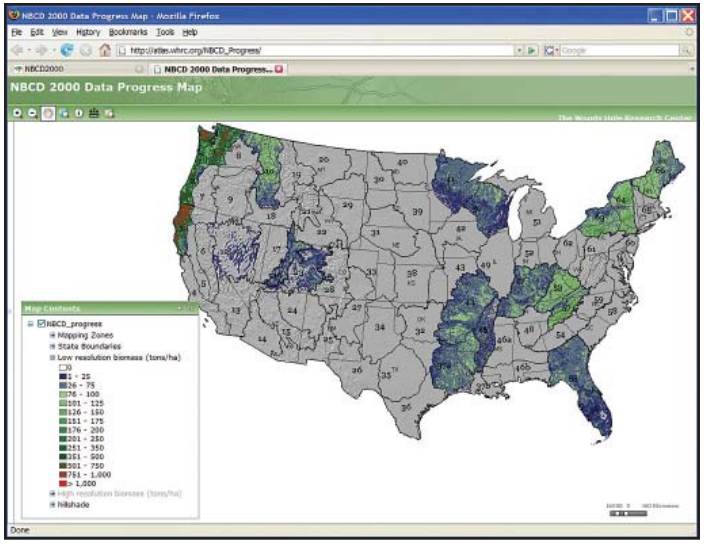
The core data layers for estimating carbon are two nationwide estimates of elevation: the 2000 Shuttle Radar Topography Mission (SRTM) digital surface model and the National Elevation Dataset (NED) digital terrain model. Essentially, these datasets are "differenced" to produce an estimate of vegetation canopy height that is used in subsequent biomass prediction.

The key tool in the ArcGIS NBCD toolbox generates this difference layer for each mapping zone. The necessary SRTM and NED tiles, acquired from the United States Geological Survey (USGS) seamless server (seamless.usgs.gov), are mosaicked. The NED surface is subtracted from the SRTM surface using raster math. In the final operation, the raster is clipped to the mapping zone boundary and converted to the proper bit depth required by the statistical modeling routine.

The tool performs a series of multistep, often time-consuming, GIS tasks within minutes. Previously, these tasks could require nearly an hour of setup time but now they are fully automated. Automating these tasks using Python scripting has greatly increased processing efficiency and saved hundreds of hours. Because help for the toolbox GUIs has been completely documented, new NBCD2000 team members can quickly become familiar with each tool and perform data processing with greater ease and confidence.

Providing Invaluable Information

The NBCD2000 dataset will be an invaluable information source for carbon stock assessment and flux modeling in the United States. Once completed for the conterminous United States, it will provide a baseline for comparing data products from the next generation of advanced earth-observing remote-sensing platforms. Funded by NASA's Terrestrial Ecology Program with support from the USGS Landfire Initiative, the NBCD2000 project directly supports the North American Carbon Program, a major component of the U.S. Climate Change Research Program. Clearly, a dataset of this scale could not be generated without a sizable team effort and the great benefits in efficiency, accuracy, and scalability afforded by the range of automated tools available through the desktop GIS environment.



Using an ArcGIS Server 9.2 map service, completed height and biomass data has been posted on the WHRC Web site.

About the Author

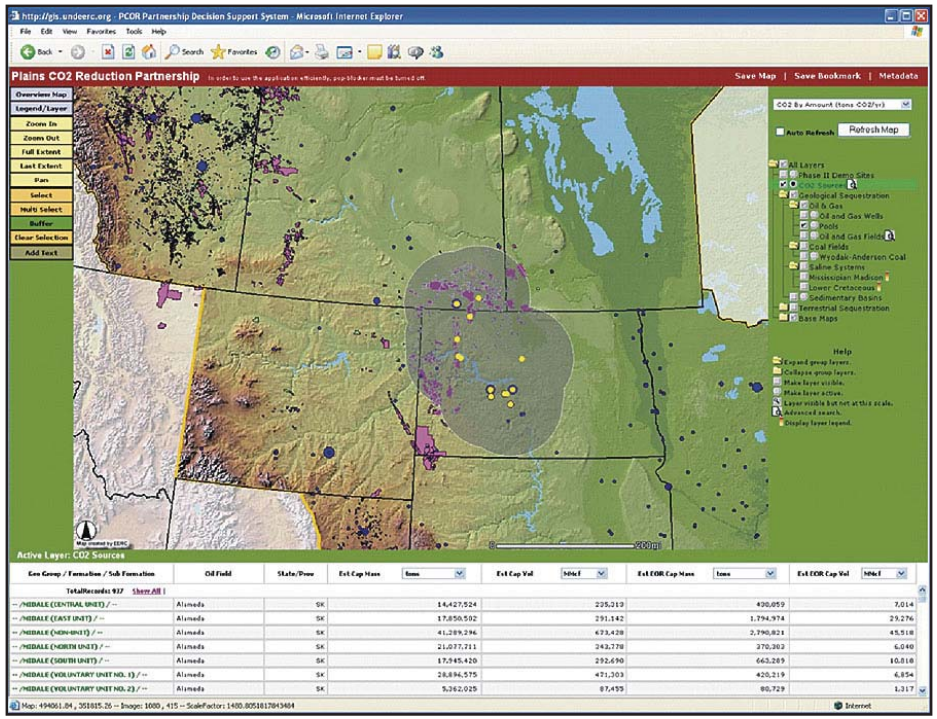
Gregory J. Fiske, a research associate with WHRC, is a geographer and an aspiring Python programmer.

(Reprinted from the Summer 2008 issue of *ArcUser Online*)

Carbon Dioxide Sequestration Communications Supported by GIS

A Study of the Great Plains of North America

Affordable energy not only fuels our vehicles and electrical plants, it also fuels our economy and our quality of life. However, most of today's energy technologies release carbon dioxide (CO_2) into the environment, and there is growing concern that CO_2 in the atmosphere might affect global climate and weather.



The Plains CO_2 Reduction Partnership Decision Support System showing the selection of oil pools (potential CO_2 sequestration sites) within 75 miles of selected CO_2 sources.

The University of North Dakota Energy & Environmental Research Center (EERC) is leading an international team to develop opportunities for CO_2 sequestration in the Great Plains of North America. This team, the Plains CO_2 Reduction (PCOR) Partnership, is one of seven regional partnerships established by the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) to determine the most suitable technologies, regulations, and infrastructure needs for carbon capture, storage, and sequestration in different areas of the United States and Canada.

Through the collaboration of more than 50 government, industry, and environmental groups, the PCOR Partnership is currently characterizing CO_2 sources and sequestration opportunities in nine U.S. states and three Canadian provinces—in all, nearly 1.4 million square miles.

A major component of this characterization is creating an inventory of large stationary sources of CO_2, identifying and mapping geologic and terrestrial targets, or sinks, for CO_2 sequestration across the PCOR Partnership region. Knowledge of the character and spatial relationships of sources, sinks, and regional infrastructure is basic to developing and assessing approaches to economical CO_2 sequestration.

The most efficient way to communicate this information to the partners has been through a GIS-enabled Web site built with ArcIMS software*, which was selected following competitive evaluation because of its versatility in both the GIS and Web environments. This site is a major component of a larger Web-based decision support system (DSS) that provides the research team with a single point of access to a wide variety of research data for the evaluation of sequestration data and the development of potential scenarios. This password-protected Web-based platform contains the tools and capabilities designed to deliver functional and dynamic access to data acquired through the project. The data is housed in a relational database and accessed through a map-based portion of the Web site. More traditional Web pages provide access to relatively static data, such as links to reports, CO_2-related Web sites, terrestrial maps, and snapshots of regional data.

The Web-based GIS portion of DSS is designed using ArcIMS, which provides a scalable framework for GIS Web publishing.

*ArcGIS Server is now ESRI's Server GIS technology. ESRI has discontinued development of ArcIMS. Learn more about ArcGIS Server at www.esri.com/arcgisserver.

GIS technology enhances the users' understanding of regional opportunities by allowing them to visualize the spatially distributed nature of the data. DSS contains several analysis methods that allow members of the research teams to browse, query, analyze, and download data regarding CO_2 generation and sequestration in the PCOR Partnership region. Researchers can use the GIS to

- Examine attributes of individual features or groups of features and their spatial relationships to other features.
- Query the underlying data to analyze the region and export selected data for manipulation in other software.
- Explore the nature of the data through thematic maps.

In addition to enabling the user to directly select features on the map, the site allows the user to employ advanced selection methods. The attribute query option is a powerful tool for finding and examining features and data based on specific data attributes. An alternative feature selection process allows for sink/source proximity analysis that can be employed through a spatial query. This approach uses the buffer tool to identify features that are located within a user-specified distance of currently selected features.

The Web-based GIS interface of DSS contains several themes of georeferenced data that are considered crucial for the PCOR Partnership project. This data includes detailed source and sink characterization information that has been collected or generated by the research team. Several base layers and associated characteristics are also available, including political boundaries, cities, regional geology, road and rail transportation, shaded relief, and land use.

The majority of the source characterization data was gleaned from public data sources, such as U.S. Environmental Protection Agency (EPA) Web sites. The database currently contains information regarding all stationary CO_2 sources in the PCOR Partnership region. Stationary sources include heat and power generation (utility, industrial, institutional, and municipal) and industrial facilities representing the food, fuels, chemicals, minerals, metals, paper/wood, manufacturing, and waste-processing industries.

Largely, CO_2 emissions were estimated using fuel utilization data or unit production emission factors (e.g., tons CO_2/gallon ethanol). Sulfur and nitrous oxide emission data was included wherever available. Emission data is initially displayed in tons CO_2/year (mass) and million cubic feet (mmcf) CO_2/year (volume); however, the ArcIMS interface has a converter for users to select different units, such as tons CO_2/year or mmcf CO_2/day.

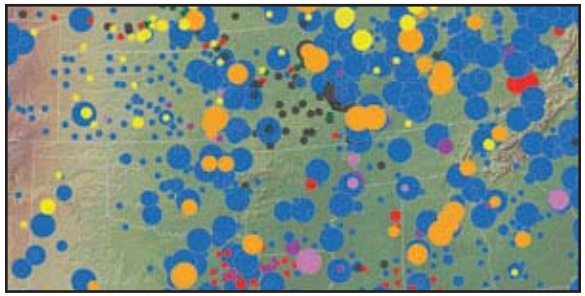
The petroleum-related data (well and field locations along with associated management, production, and stratigraphic data) was provided by state agencies or gleaned from publications; however, the level, or detail, of available data was not always consistent from state to state. The database currently contains information on more than 400,000 wells with various attributes, including operator name, well name, total depth, well type, and well status. Reservoir characteristic data was obtained by researching state agency case files for fields with a cumulative oil production greater than 800,000 barrels. This data pertains to reservoir characteristics that are necessary to perform detailed field studies with respect to CO_2 sequestration, including porosity, permeability, reservoir thickness, surface area, original oil in place (OOIP), cumulative production data, and water and oil characteristics.

(Reprinted from the Winter 2006/2007 issue of *ArcNews Online*)

National Carbon Sequestration (NatCarb)

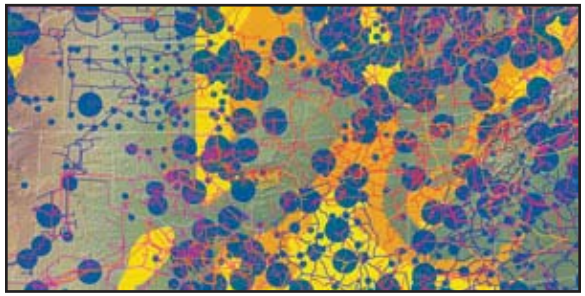
Kansas Geological Survey Data Access and Support Center

By Nicholas Callaghan

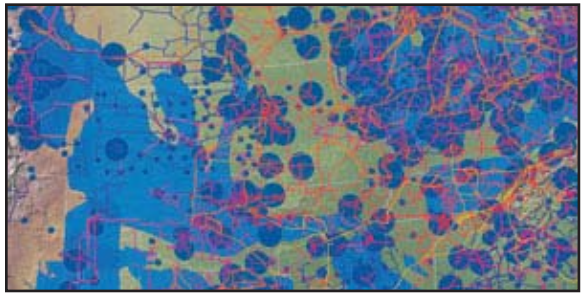


North American CO_2 Sources

North American Saline Basins



North American Power Grid with Coal Basins



North American Power Grid with Saline Aquifers

The U.S. Department of Energy's Regional Carbon Sequestration Partnerships (RCSPs) generated data for the layers displayed in the Carbon Sequestration Atlas of the United States and Canada. Geospatial data such as carbon sources, potential storage sites, transportation, and land use are required for efficient implementation of carbon sequestration on a broad scale. National Carbon Sequestration (NatCarb) is a relational database and GIS that integrates carbon storage data from the RCSPs and various other sources.

The purpose of NatCarb is to provide a national view of the carbon capture and storage potential in the United States and Canada. This digital spatial database allows users to estimate the amount of CO_2 emitted by sources (such as power plants, refineries, and other fossil fuel-consuming industries) in relation to geologic formations that can provide safe, secure sequestration sites over long periods of time. NatCarb provides access to the necessary information regarding the costs, economic potential, and societal issues of CO_2 capture and storage, including public perception and regulatory aspects.

Courtesy of Kansas Geological Survey at the University of Kansas.

(Reprinted from the *ESRI Map Book Gallery,* Volume 23)

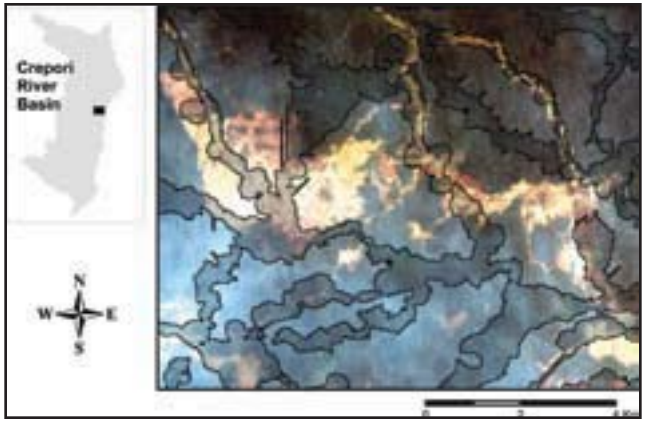
Remote Sensing Reveals Protected Forests Not So Protected

By Michael Meitner, University of British Columbia

Brazil is home to the Amazon, the Savanna Woodland (the cerrados), and the Atlantic Forest. These three different biomes are threatened by the degradation of their forests. Currently, approximately 2.3 million hectares of these biologically diverse lands are lost to deforestation each year. The survival of these forests rests with Brazil's ability to enforce the laws that are already in place to protect these areas. Environmental scientists are using GIS technology to study the extent that deforestation is continuing in Brazil's designated protected areas.

In the 1965 Brazilian Forest Code, two types of protected forests are listed: legal reserves and permanent preservation areas. Legal reserves are a percentage of privately owned land, but permanent preservation areas are defined by their geography. Historically, the delineation of protected areas and subsequent enforcement of land-use restrictions within them has been hampered by the difficulty in determining the physical boundaries of these areas currently expressed only in policy. The lack of appropriate topographic datasets and the expertise needed for manually mapping the preserves made it virtually impossible to enforce the Brazilian Forest Code over an area as large as the Amazon rainforest. As a result, the essence of the environmental legislation gradually faded away, paving the road for a generalized fragmentation of natural habitats in areas that should, by law, be preserved.

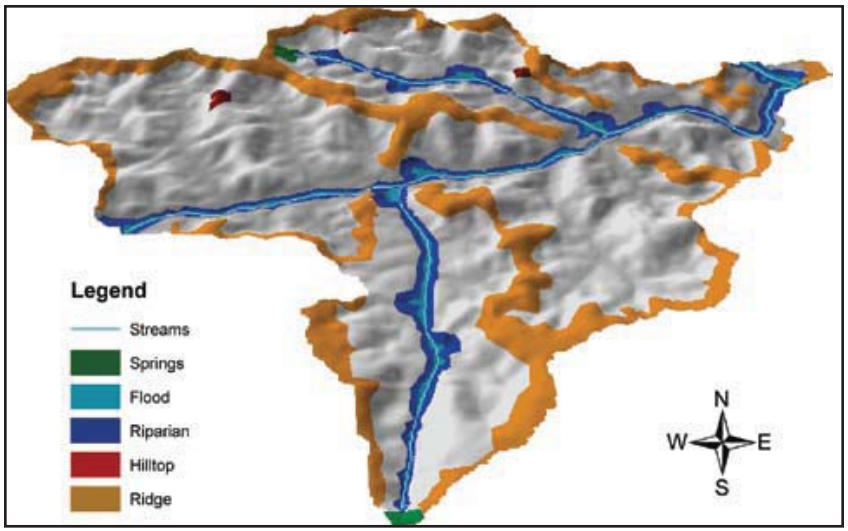
A primary step for enforcing Brazil's environmental law is to create a method for accurately mapping legally protected areas using available data. A team of international scientists from the University of British Columbia conducted a project to map the country's permanent preservation areas. This team included Carlos Ribeiro, Michael Meitner, Marcello Veiga, and Brent Chamberlain. Recent advances in GIS technology and greater availability of worldwide high-resolution digital imagery has made it possible for the team to map one of these places. The project provides the basis for a proposal to extend the project to other regions of concern.



Example map of permanent preservation areas over an existing mining site. Image is taken from IKONOS and was down-sampled to 30m. Shaded and bordered areas represent permanent preservation areas based on project results. Yellow encroachment activities become obvious within the shaded protected areas.

Using ArcGIS software to map Brazil's Crepori River basin, the scientists were able to delineate areas that should be protected from deforestation. Permanent preservation areas are defined by their topography, such as the top third of a hill's surface area, ridgelines, upland catchments, and riparian zones dependent on the width of a river's floodplain. To map these areas, the team combined Shuttle Radar Topography Mission (SRTM) data and digital hydrography datasets from the Brazilian Institute for Geography and Statistics (IBGE) to produce a hydrographically correct digital elevation model. This allowed the characterization of the landscape into layers, which depicted each of the defining aspects of permanent preservation areas. These layers were then mosaicked to produce the final map of the permanent protected areas for the basin.

Although the Crepori River basin is a small percentage of the Amazon, the data collected for that area was extensive. Eventually, the team wants to automate the delineation routines used in the study so these can easily be replicated across the rest of Brazil. Creating one map of all permanent preservation areas would make Brazil's progressive legislation enforceable.



Spatial distribution of Brazilian permanent preservation areas in a portion of the Crepori River Basin.

The results of this study show that permanent preservation areas create ecological corridors that connect all of the biomes in the area and therefore contribute to the protection of the biodiversity of the region. The results also make clear that some of these legally protected areas are not being conserved.

The team hopes that their maps create awareness of present and potential land-use conflicts, create a focus for where new development should occur so as not to interfere with permanent preservation areas, and provide a framework for setting up natural preserves across Brazil.

Shuttle Radar Topography Mission Data Available

SRTM is a specially modified radar system that flew onboard the space shuttle *Endeavour* to acquire elevation models. SRTM obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth thus far. The data was processed at the Jet Propulsion Laboratory and is being distributed through the United States Geological Survey's EROS Data Center. The elevation models derived from SRTM are used in GIS. They can be downloaded for free over the Internet, and their file format (.hgt) is supported by ESRI's software. Learn more about SRTM at http://edc.usgs.gov/srtm/data.

(Reprinted from the Fall 2007 issue of *Environmental Observer*)

Conserving Bolivia's Critical Resources

GIS Helps Gauge Land Change Effects on the Nation's Endemic Biodiversity

By James Toledano, J. Ronald Eastman, and Florencia Sangermano, Clark Labs, Clark University; and Tim Killeen, Conservation International

Highlights

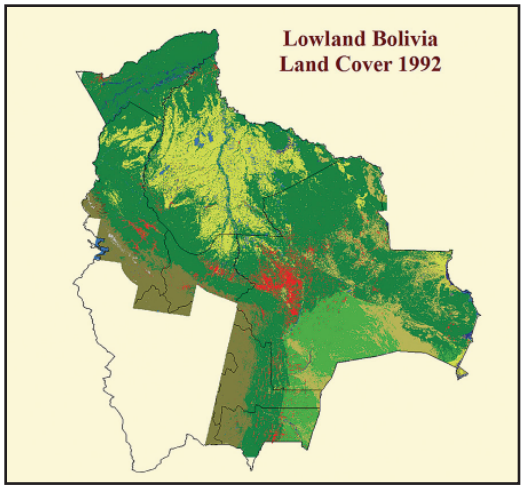
- Land Change Modeler is now an extension for ArcGIS software.
- GIS contributes to the accuracy of mapping the potential of land-cover classes.
- Software provides a means to combat threats, such as economic development.

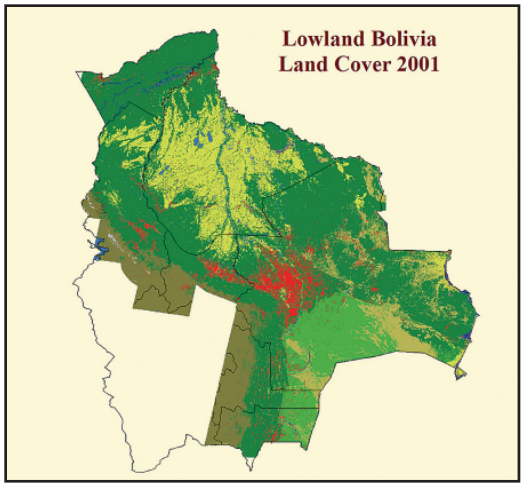
Due in part to a tremendous amount of economic growth in recent decades, the Bolivian lowlands saw forest loss of almost 3 million hectares between the years of 1992 and 2004, with almost half of this loss coming between 2001 and 2004 alone. This land change is expected to be the major contributor to biodiversity loss (even more important than climate change) and contributes to habitat degradation, fragmentation, and destruction. Indeed, the rate of deforestation is second only to that of Brazil. With forests dominating more than 65 percent of the land cover in lowland Bolivia, it is essential that this land-change dynamic be appropriately analyzed, particularly as we now know tropical forests are a critical component for maintaining climate system function and that they also represent the habitat for a wide range of species.

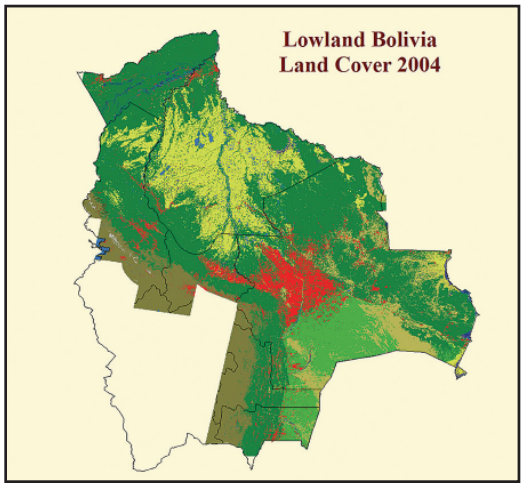
Conservation International, based in Arlington, Virginia, is an organization at the forefront of preserving natural systems in a sustainable manner. It has focused much attention on land-cover change in the Amazon, particularly in Bolivia, and it has relied more in recent years on the scientific application of GIS for insights into managing habitat loss and predicting future scenarios of change. To better implement this effort, Conservation International has prioritized the oversight of the development of essential integrated tools for identifying hot spots and conserving habitat and biodiversity—tools to better manage, monitor, and prioritize the risks to the environment associated with economic development.

Clark Labs (an ESRI Business Partner located in Worcester, Massachusetts, and based within the Graduate School of Geography at Clark University) partnered with Conservation International over several years to develop a land-change modeling software environment to analyze land-cover change and assess the potential impacts of these scenarios on biodiversity.

The result of this collaboration was the development of the Land Change Modeler (LCM), implemented within Clark's IDRISI GIS and image processing software and recently as an extension for ArcGIS software.







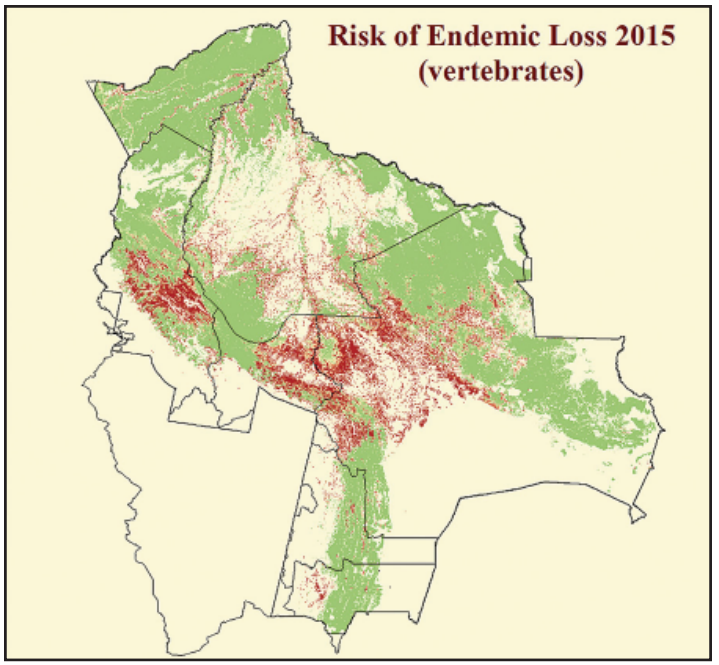
These land-cover maps depict dramatic lowland deforestation (red) over time between 1992, 2001, and 2004 (data: the Geography Department at Bolivia's Noel Kempff Mercado Natural History Museum).

Bolivian Land-Change Dynamics and Implications on Biodiversity

For a recent showcasing of LCM, Clark used land-cover maps depicting dramatic deforestation over time that were developed by the Geography Department at Bolivia's Noel Kempff Mercado Natural History Museum for that nation's lowlands. These maps showed forest change that occurred between 1992 and 2001. A set of 28 static and dynamic driver variables that may have impacted this change, such as proximity to infrastructure, slope, and soil type, were also included. Information on known road improvements for Bolivia as part of the planned intervention input to the prediction phase further refined the model. For this project, a multilayer perceptron neural network was used to create a predictive model, relating the observation of deforestation with the driver variables. Clark chose this method because of its high accuracy for mapping the transition potential of land-cover classes. To assess the quality of the model, a prediction was made to 2004 and the output was validated against known conditions in 2004.

Once the model was calibrated, additional future scenarios were then produced. One such scenario included both a soft and hard prediction of land change in the Bolivian Lowlands for the year 2015. The hard prediction yielded one possible scenario of the locations of change, while the soft prediction gave an indication of the deforestation vulnerability in 2015. Results from this scenario were then combined with biodiversity data to uncover the potential impact on biodiversity.

Using collections of species range polygons, initially supplied by NatureServe and subsequently recalibrated in Land Change Modeler for ArcGIS, a species richness map was developed for all birds, mammals, and amphibians. A total of 73 species endemic to Bolivia were identified, including 36 amphibians, 16 mammals, and 21 birds. This map was combined with the 2015 soft prediction (deforestation vulnerability map) to derive a risk of biodiversity, or endemic loss.



A species richness map was developed, then combined with the 2015 soft prediction to derive a risk of biodiversity, or endemic loss.

Habitats Already Lost

The results are alarming. Assuming business as usual, the potential forest loss could be devastating to biodiversity in Bolivia. For example, one of the endemic species, the masked antpitta (*Hylopezus auricularis*), an already threatened species, is projected to lose one-third of its habitat by 2015. Indeed, for the base time period of this study, 2001–2004, 4 percent of the current endemic mammal habitat has already been lost. The implications of land change on biodiversity are occurring now.

Land Change Modeler for ArcGIS provides a means to combat threats, such as economic development, and to assist those engaged in important conservation practices to prioritize threatened environments. Clark Labs, in conjunction with Conservation International, is currently conducting training in the use of these important tools for land-use planning and sustainable development in countries undergoing high biodiversity loss to further prioritize their planning interventions.

About the Authors

James Toledano is executive director of Clark Labs, Clark University. Ron Eastman is the director and founder of Clark Labs. Florencia Sangermano is a research associate at Clark Labs. Tim Killeen is a senior research scientist at the Center for Applied Biodiversity Science, Conservation International.

More Information

For more information on Conservation International, visit www.conservation.org. For more information on Land Change Modeler for ArcGIS, contact Clark Labs (www.clarklabs.org). Noel Kempff Mercado Natural History Museum is a recipient of GIS software from ESRI's conservation programs and has received additional support from the Bolivian government, Conservation International, The Nature Conservancy, and the World Wildlife Fund.

(Reprinted from the Spring 2008 issue of *ArcNews* magazine)

Since 1969, ESRI has been giving customers around the world the power to think and plan geographically. The market leader in geographic information system (GIS) solutions, ESRI software is used in more than 300,000 organizations worldwide including each of the 200 largest cities in the United States, most national governments, more than two-thirds of Fortune 500 companies, and more than 5,000 colleges and universities. ESRI applications, running on more than one million desktops and thousands of Web and enterprise servers, provide the backbone for the world's mapping and spatial analysis. ESRI is the only vendor that provides complete technical solutions for desktop, mobile, server, and Internet platforms. Visit us at www.esri.com.

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