CSU Geospatial Review
GEOGRAPHIC INFORMATION SCIENCE IN THE CALIFORNIA STATE UNIVERSITY SYSTEM
VOLUME 8 • SPRING 2010

Sonoma

Using LiDAR to Assess Aboveground Carbon Stored in Tropical Rain Forests

Although a comprehensive global agreement to limit carbon emissions did not emerge from the December 2009 U.N. Climate Change Conference (COP15) in Copenhagen, there was broad agreement on, and $3.5 billion of initial funding pledged for, the U.N. initiative called "Reducing Emissions from Deforestation and Forest Degradation (REDD)". Roughly 15-20% of global greenhouse gas emissions come from the cutting of forests for timber and agricultural expansion, mostly in tropical countries.

REDD seeks to slow this source of carbon emissions through policy and economic incentives that promote forest protection and sustainable forest management. A key component of a global REDD agreement is the accurate and transparent measurement, reporting and verification of carbon stored in vegetation biomass (which is roughly 50% carbon).

It is estimated that tropical forests store 59% of global carbon found in vegetation (Dixon et al.,1994). However, there is considerable uncertainty in our knowledge of carbon pools and dynamics in tropical forests (Houghton, 2005). Ground-level data, considered the most accurate, comes from small plots that are sparsely distributed across the tropics. Most of the data are actually for "aboveground" biomass (AGB), not including carbon stored in roots and soils, and typically estimated from an allometric relationship of AGB to tree diameter for a climate zone—species characteristics (e.g., woody density) are often ignored. Satellite image analysis is key to estimating forest carbon stocks and emissions from deforestation at regional and broader scales. However, these assessments are typically done by assuming even distribution of biomass in forest types and based on inaccurate estimates of deforestation rates (Houghton, 2005).

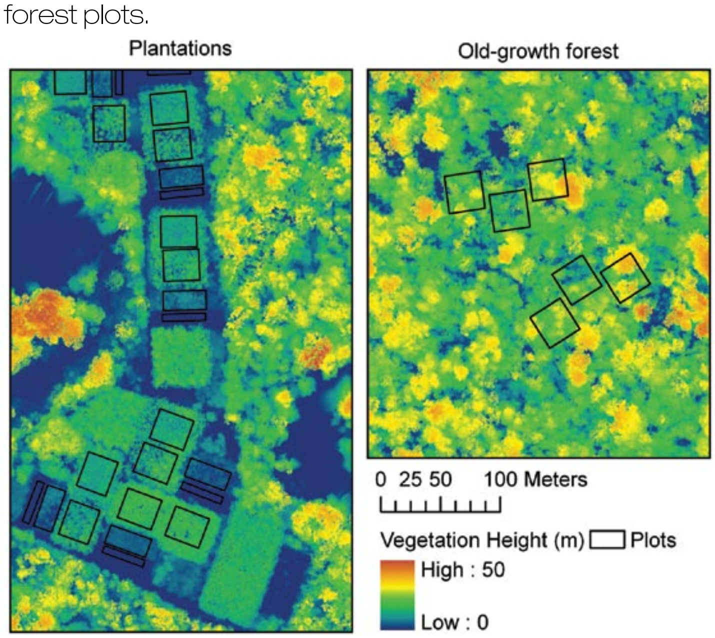
Light detection and ranging (LiDAR) is a highly successful technology for mapping the fine-scale variability of AGB over broad spatial extents (Drake et al., 2002; Lefsky et al., 2002). Full-waveform LiDAR records a detailed height distribution of surfaces illuminated by a laser pulse in footprints from 1 to 80m, while small-footprint LiDAR records discrete heights at peak returns of light within 0.25- to 0.60-m footprints (Lefky et al., 2002).

Here we describe research with a small-footprint, first-return LiDAR sensor for estimating AGB for a range of tropical forest types. The instrument was flown in a helicopter over the La Selva Biological Station in Costa Rica (84°00′13.0″ W, 10°25′52.5″ N). This site receives 4 m of rain annually, and the lush tropical forests that grow there

cont. page 6

Figure 1 (above): A forest view from the La Selva Biological Station.

Figure 2 (below): Example of LiDAR-derived digital canopy model (DCM) with plantations and old-growth forest plots.



INSIDE

SAVE THE DATE
Please join us at the 2010 ESRI International User Conference in San Diego, California, from July 12-16.

DIRECTOR'S MESSAGE 2010

Offshore Research

When we got started in the late 1980s, we had a handful of campuses using GIS. By the late 90s, we were up to 20 or so. This year we've added the 23rd and final campus, the California Maritime Academy, located in Vallejo, California, but with the training ship Golden Bear that literally takes it around the world. Initiated in 1929 as the California Nautical School to train officers of the merchant marine, in 1995 it became a campus of the CSU, having expanded from its original role to offer bachelor's degrees in international business and logistics, facilities engineering technology, global studies and maritime affairs, marine engineering technology, marine transportation, and mechanical engineering.

Some exciting GIScience applications are expected to arise from this new member of our community. Jim Buckley, the Associate Dean for Simulation, and the CSU GIS Board Member from the Academy, is pursuing our technology to enhance methods and improve datasets for maritime hazard response. The simulation center accurately predicted the movement of the Cosco Busan oil spill in 2007. We recently toured the simulation facilities and got a bit dizzy on their simulated ship bridges. Expect to see a report on this work in next year's CSU Geospatial Review.

Jerry Davis, *Director*, CSU GIS Specialty Center
San Francisco State University

Pomona

Sprawl Fighting GIS Tools to be Developed by Cal Poly Pomona CGISR

The Cal Poly Pomona Center for GIS Research is now in the second year of a multi-year project, led by Dr. Mike Reibel and currently supported by the Leonard Center for Transportation Research at CSU San Bernardino, to promote and enhance the use of GIS in local and regional planning for smart growth.

The project began in 2008-09 with a capability gap analysis and determination of GIS best practices for transportation planning by local agencies, using San Bernardino and Riverside Counties as a case study area. The three major findings from that study are that: 1) GIS capabilities vary greatly across local governments; 2) The passage of anti-sprawl law SB 375 has radically increased the demands on local government GIS and geospatial capabilities, and 3) GIS integration of land use planning and transportation planning functions, which is the most critical need created by SB 375, is often the weak link even for local governments with relatively sophisticated GIS capabilities.

The current stage of the project at CGISR builds on those findings by developing GIS tools (custom ArcGIS extensions) to assist local agencies in duplicating, as nearly as possible, the actual regional planning process mandated under SB 375. SB 375 is a statute designed to help slow global warming (and incidentally to reduce air pollution and urban sprawl) by steering resources toward a comprehensive transit oriented housing and land use development strategy to reduce miles driven.

The SB 375 mandate requires far more integration of land use planning with transportation planning, and far more geospatial analysis than was previously necessary. It therefore represents the most significant recent change, and the greatest challenge, with respect to local and regional planning agencies' use of geospatial data and GIS.

The proposed SB 375 toolkit to be developed by the CGISR will consist of automated custom GIS applications and data layers. These tools will allow GIS literate users in local agencies to create scenarios approximating the plans required by SB 375 of the seventeen metropolitan planning organizations (MPOs) in California. By automating the necessary GIS processing and analysis steps and building in functions derived from empirical research on land use patterns and transportation behavior, the tools will help maximize local input into the regional SB 375 planning process and encourage the development of alternative planning scenarios.

The toolkit will be developed as a custom extension to ArcGIS (the overwhelming GIS software choice of local governments). Under an agreement with the Southern California Association of Governments (SCAG), the largest MPO, the toolkit will come loaded with the geospatial data used by SCAG in the regional planning process for its six county greater Los Angeles area. If resources are available, future phases of the Cal Poly Pomona effort will focus on incorporating relevant geospatial data for the rest of California, promoting the use of the toolkit for anti-sprawl scenario development, and training local agency personnel in its use.

MORE INFORMATION:
Michael Reibel
Geography Department
CSU Pomona

San Francisco

Using R for Geographic Analysis and Education

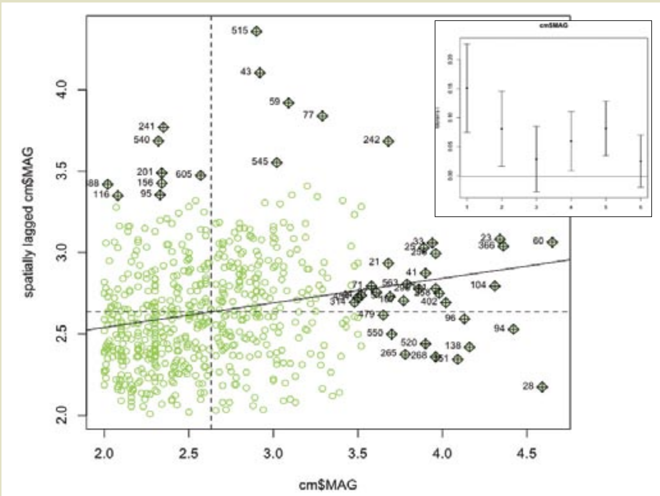


Figure 1: Moran's I correlogram and scatterplot

Recent improvements by ESRI to the ArcGIS Spatial Statistics Toolbox have reduced the need to rely on external programs such as SPSS to perform or teach statistical analysis. However, many commonly applied statistics such as logistic regression have yet to be added to ArcGIS, requiring software that can be expensive for students to access off campus, or lacking required functionality. For many CSU faculty and students an attractive alternative has been R.

R is an open source software package and programming language designed for statistical analysis and graphical representation of data. R has become increasingly popular throughout a variety of industries and disciplines because it is free, powerful, well-documented, produces effective graphics, and allows users to develop custom tools of their own. Since its release in 1997, over 2,100 packages of tools have been developed and contributed by users, making R a remarkable resource for both traditional and novel statistical approaches (R Development Core Team, 2010).

Several R packages are dedicated to working specifically with spatial data. A variety of vector and raster data formats can be imported into R, analyzed, and exported back to shapefile, KML, geotiff, etc. Once the data are imported, users can perform, for example, geostatistical analysis, spatial autocorrelation tests, autocovariate regression, point pattern analysis (Fig. 1). Some spatial packages have more focused application such as BIOMOD for habitat distribution modeling or DCluster for identifying clusters of disease.

R is particularly well-suited for manipulating data tables and generating graphics. Functions typically associated with database or matrices software such as joining, summarizing, and transposing, can be applied with little effort, and data can be read directly from text files, SQL enabled databases, or Excel spreadsheets. Graphics can be produced to represent data in just about any way imaginable and exported to PDF or other formats (Fig. 2). Since original data are not altered by R, and the workflow is recorded in a script, users can readily review, modify, or rerun a process, making R an exceptionally organized and efficient way to work.

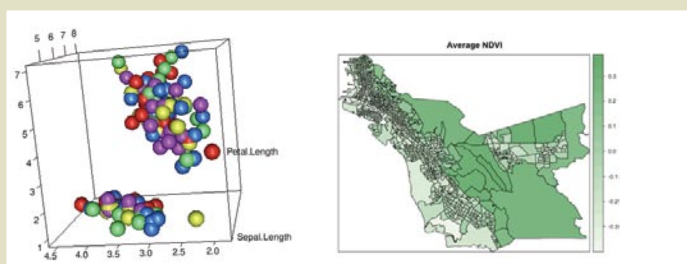
R can also be interfaced with Python. At San Francisco State we have begun developing R-based tools for ArcGIS Toolbox using Python, and have introduced this capability to students in our extended learning GIS programming course. Calling R from Python is fairly straightforward using the R-(D)COM programming interface, which is the method implemented in the newly released version of Hawth's Tools.

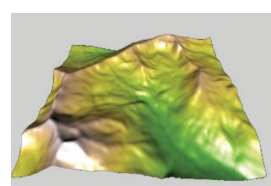
Despite the advantages of using R over other statistical programs, the scripting interface can be a hindrance, particularly to instructors who might otherwise use it as a teaching tool. At a basic level, however, R is more similar to a command line operating system than to programming with C++ or Python. R automatically recognizes table data structures and has several functions that make learning control structures such as loops unnecessary. Having recently offered a two-day statistics course using R at SFSU, our experience has been that students responded positively to the material, perform as expected along a normal distribution, and were comfortable learning the statistics so long as R syntax remained simple. For those wary of learning a scripting language, the R Commander graphical user interface is an excellent way to get started with R.

As with other open source successes such as MySQL, Firefox, or Python, R has been embraced by motivated and enthusiastic user and development community. The result is a robust and reliable software that is accessible to beginners but provides the utility and flexibility for professional scientific research. At San Francisco State R has become a staple analytical tool, and we encourage those that have not yet used R to download it and give it a try.

R Development Core Team "R: A Language and Environment for Statistical Computing" http://www.R-project.org (accessed December 9, 2009)

MORE INFORMATION:
Seth Hiatt, Associate Director
Institute for Geographic Information Science
San Francisco State University





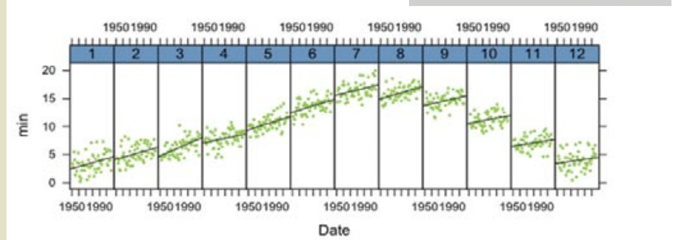


Figure 2: Examples of the variety of graphics that may be produced in R, illustrating interactive, 3D, spatial, and conditional plots

Forest Fire Severity Mapping Using Satellite Imagery and GIS for Carinthia, Austria

Wildfires are a natural occurrence in many parts of the world, but in some locations recent changes in climate and population has led to an increase in fire frequency and intensity. Recent studies of climate change trends in the Austrian Alps predict that the risk of wildfires will dramatically increase in the future, making it necessary for emergency management operations (EMOs) to monitor and prevent hazardous wildfire events. EMOs in Austria do not currently have a mechanism for monitoring fire risk, leaving communities vulnerable to the threat of future wildfire. Therefore, locations that are highly susceptible to fire need to be identified in order for EMOs to conduct thorough analyses and create hazard event plans for at-risk areas. Several models and methods have been developed to identify areas vulnerable to wildfire, i.e. the California Department of Forestry and Fire Protections Fire and Resource Assessment Program CDF-FRAP Fire Threat Model and FARSITE, though few have been developed for alpine climates. The objective of this research is to develop a mechanism for identifying wildfire risk in Carinthia, Austria.

The developed framework is modeled after current fire severity threat identification models and CDF_FRAP fire threat model which integrates available remotely sensed vegetation and elevation data into ESRI's ArcGIS along with additional information relating to road networks and population. Five variables representing vegetation type, slope, canopy cover, vegetation growth stage, and proximity to roads were selected as the most vital variables to predict fire severity in an alpine climate. Each input raster was projected, resampled, and reclassed using ArcMap tools. Because each variable contributes differently to potential fire threat, the variables were assigned weights which reflected the importance of each variable in the final calculation. The equation below was utilized to calculate the fire threat of an area using raster calculator in the Spatial Analyst Toolbar in ArcGIS.

Fire Threat =
[0.35(VT)] + [0.25(S)] + [0.15(CC)] + [0.15(GS)] + [0.10(PtR)]

Where each of the following fire susceptibility factors is ordinarily scaled from 1 (low) to 4 (very high):

VT – Vegetation Type
S – Slope
CC – Canopy Cover
GS – Growth Stage
PtR – Proximity to Road

The proposed framework was tested for a location in Upper Carinthia. It is important to note that this framework and resulting fire threat identification operates under the assumption that optimal conditions for fires exist. Some of the characteristics of such conditions are low relative humidity, high winds, high temperatures, and low fuel moisture. The resulting map output (Figure 1) identifies areas that are susceptible to wildfire and assigns a rank (low, moderate, high, very high) for the overall sensitivity of a particular area. The map output delineated areas that were at minimal, moderate, and high risk to fire occurrence. Methods explored in this study outline a successful process utilizing GIS software, remotely sensed imagery, and vector data to create a model to map wildfire risk in Carinthia, Austria.

Acknowledgements

This research was funded by the Austrian Marshall Plan Scholarship. Special thanks to Dr. Gernot Paulus, Carinthia University of Applied Sciences, Villach, Austria, for guiding and assisting in conducting this research while also providing valuable information about EMOs in Carinthia Austria, and to Paul Hardwick, San Diego State University, for providing important information about San Diego County EMOs, without which this research could not have been completed.

MORE INFORMATION:
Nicole Simons, Joint Doctoral Student
San Diego State University/University of California at Santa Barbara
nsimons@mail.sdsu.edu

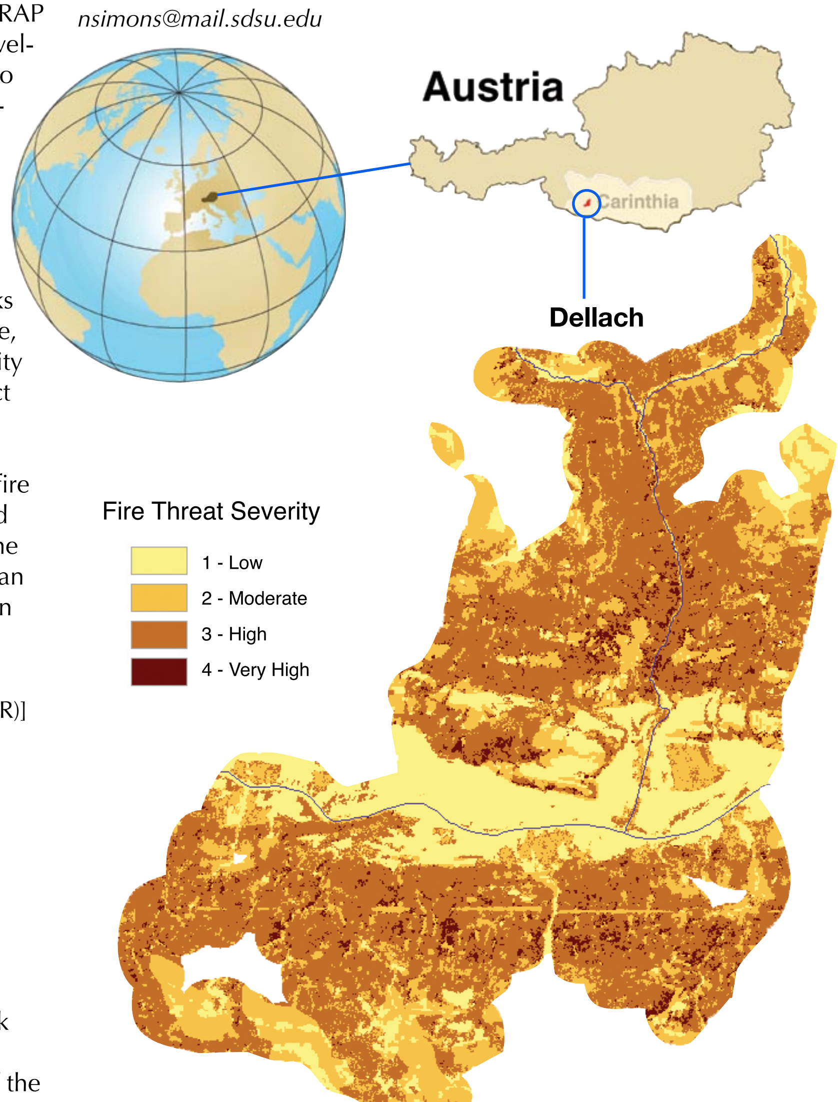


Figure 1: Fire severity threat identification map for Dellach area of Carinthia, Austria.

Humboldt

Using PPGIS to Study Rural Ethnic Entrepreneurship

People living in a place possess unique knowledge about their surrounding environment. In an effort to incorporate this information into our research on rural entrepreneurship, we employed public participation GIS. Public participation GIS (PPGIS) involves a union of academic practice with local knowledge production. PPGIS gives voice to marginalized groups by allowing them to share their knowledge (e.g. thoughts, expertise and observations) and visualize data in a socio-spatial context. It's an effective way for community members to collaborate to identify what they know to be important about the local community and/or environment.

We employ a mixed-methods approach to better understand rural entrepreneurship and to examine experiences and social network structures associated with ethnic entrepreneurs. Our work identifies factors leading to successful ethnic-owned businesses and contributes to an understanding of the social networks and local resources using a socio-spatial, community-focused approach, which consider space, place and social indicators in a holistic fashion. Our model improved engagement in community and economic development with groups whose voices need to be heard. Ultimately, we seek to identify and examine rural social networks from a spatial perspective.

Our approach involves partnering with a local Mendocino County Latino-focused nonprofit working on community engagement. Because a list of local Latino owned businesses didn't exist, we used PPGIS to generate this list. GIS maps of the communities were placed on tables for participants to identify places where they participate in community, church, professional, neighborhood, fundraising, school, volunteer, and service groups and activities, as well as the locations of Latino owned businesses. The base maps included different landmarks, such as schools and churches. We also interviewed community leaders with knowledge of Latino owned businesses. We generated a list of 92 Latino owned businesses in Mendocino County, which were ground truthed with Latino community members.

After marking locations on maps, participants could visualize where, and to what degree, they are integrated into the community. This visual representation of a highly involved Latino community helps to counteract media coverage that negatively portrays Latinos and builds confidence and capacity of the community. This data was geocoded onto the county base map for further analysis. Using PPGIS, it was clear that Latinos in Mendocino are civically engaged and active in multiple arenas.

Another community mapping exercise engaged participants to identify Latino community needs and locations. After a list of needs was generated by participants, themes were identified. Thematic maps were placed around the room for participants to mark where these community needs are located. For example, a need for bilingual teachers was indicated on the bilingual services thematic map. Participants then marked on this map where bilingual teachers are needed.

At this second mapping exercise, the research team also asked participants to complete a worksheet indicating their skills. People chose from a list of possible skills, such as bookkeeping, construction, house painting, yard work, tutoring, and teaching. Respondents also indicated the closest cross streets to their home. Residents' skills were then geocoded onto a map according to their cross streets. Mapping this information allows for visual comparison of the locations of community needs and community skills in order to match people's skills to community needs. Through this exercise, community members can better identify entrepreneurial opportunities built upon their own community resources.

Participatory mapping exercises enhanced this research by articulating community perceptions while helping people visualize their involvement in and connection to their community. We share this information back with community leaders to assist in further strengthening of local community capacity and economic development opportunities.

MORE INFORMATION:
Steven J. Steinberg, Professor and Director
Institute for Spatial Analysis
gis@humboldt.edu

Sheila L. Steinberg, Professor and Director of Community Research
California Center for Rural Policy

Sarah M. Keeble, Research Associate
Humboldt State University

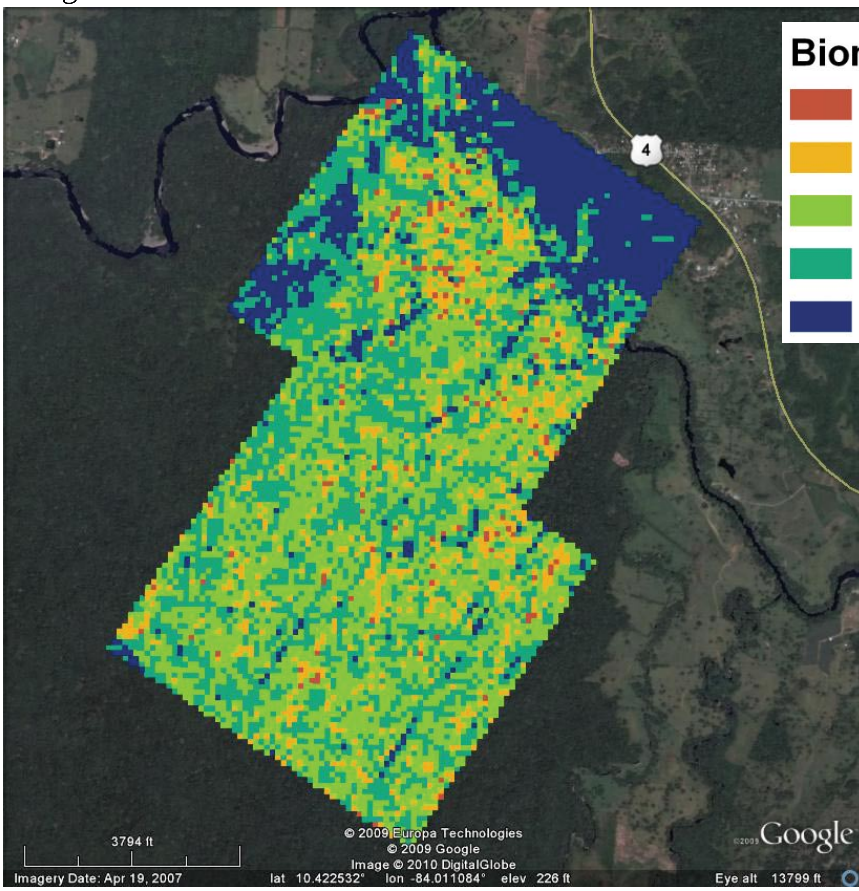


Figure 3: Example of biomass estimated with LIDAR.

include >400 tree species (Fig. 1). For this research, we used field AGB data from plantation, managed parkland forest, and old-growth forest plots. Plantation AGB estimates were very accurate as they came from allometric equations derived for the species in the plots, while the old-growth and managed forest plots used a more general equation for tropical wet forests. A digital canopy model (DCM), or raster of vegetation height, used in this analysis was derived in Clark, et al. (2004). We overlaid plots (0.04 to 0.13 Ha, 83 plots) over our DCM (Fig. 2) and calculated LiDAR metrics from cell values within plots, including mean, mean of the 95th percentile, median, maximum, and standard deviation of heights, among others. We then explored single- and two-variable regression models to estimate AGB from LiDAR metrics. We used a generalized linear regression technique that accommodated autocorrelated residual error from closely-spaced plots.

Our best model included plot-level mean and maximum height, with an r^2 of 0.90 and root mean square error (RMSE) of 38.3 Mg/ha. When we constrained the analysis to plantation plots, which had the most accurate field data, the r^2 of the model increased to 0.96, with RMSE of 10.8 Mg/ha (32 plots). We mapped AGB at 30-m using the model with all plots (Fig. 3). Old-growth forest covers most of the LiDAR dataset, with relatively high AGB values interspersed with low AGB resulting from large canopy gaps. The northern part of La Selva has a mix of plantations and abandoned pastures, with relatively low AGB values. The western side of the map covers a secondary forest with moderate AGB values.

There are challenges in implementing this technology in the tropics, including heavy cloud cover and high acquisition costs. However, this study supports conclusions from other studies that LiDAR is the premier sensor for accurately mapping the spatial variability of AGB over a landscape. LiDAR thus has the potential to advance our knowledge of tropical biomass distribution and help in monitoring and verifying commitments in carbon emission agreements.

Acknowledgements

This research was funded in part by a NASA Carbon Cycle Science grant (NNG05GE56G, Dr. Roberts), grants from the National Science Foundation (DEB-0129038, Dr. David Clark; DEB-9975235, Dr. Ewel), and the Andrew W. Mellon Foundation.

References

Clark, M. L., Clark, D. B., & Roberts, D. A. (2004). Small-footprint LiDAR estimation of sub-canopy elevation and tree height in a tropical rain forest landscape. *Remote Sensing of Environment,* 91(1), 68-89.

Dixon, R.K., Brown, S., Houghton, R.A., Solomon, A.M., Trexler, M.C., & Wisniewski, J. (1994). Carbon pools and flux of global forest ecosystems. *Science,* 263 (5144), 185–190.

Drake, J. B., Dubayah, R. O., Clark, D. B., Knox, R. G., Blair, J. B., Hofton, M. A., Chazdon, R. L., Weishampel, J. F., & Prince, S. D. (2002). Estimation of tropical forest structural characteristics using large-footprint LiDAR. *Remote Sensing of Environment,* 79, 305-319.

Houghton, R.A., (2005). Aboveground forest biomass and the global carbon balance. *Global Change Biology,* 11, 945-958.

Lefsky, M.A., Cohen, W.B., Parker, G.G., & Harding, D.J. (2002). LiDAR remote sensing for ecosystem studies. *Bioscience,* 52(1), 19-30.

MORE INFORMATION

Author: Matthew Clark,
Center for Interdisciplinary Geospatial Analysis,
Sonoma State University
Collaborators:
Dar Roberts, University of California, Santa Barbara;
David Clark, University of Missouri-St. Louis, St. Louis, MO;
John Ewel, University of Florida, Gainesville, FL

Quantifying Urban Forest Function and Value:
Effects of Chico, California's Street Tree Management on Carbon Sequestration and Energy Conservation

It is commonly known that trees provide many environmental benefits that reduce a community's carbon emissions and improve aesthetics. By shading buildings and pavement, trees lessen urban heat island effects, leading to reduced air conditioner use in the summer. In the winter months, properly selected deciduous trees allow sunlight exposure, block cold winds, and reduce storm water runoff to creeks and rivers. Trees also benefit retail business by creating aesthetically pleasing surroundings that influence shoppers to stay longer in business centers like downtown Chico. Trees also improve air quality by releasing oxygen and sequestering CO_2 and volatile organic carbons, which they convert to wood during their growth process. Though their benefits are tangible, it has long been difficult to calculate a dollar value for the services that an urban forest provides.

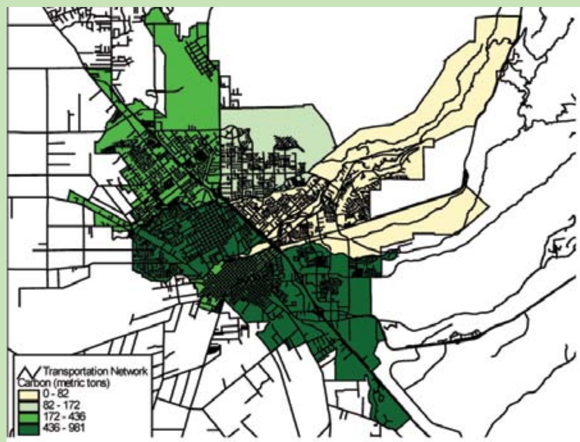
Chico is honored by the Arbor Day Foundation as a "City of Trees", and it owns and maintains approximately 31,400 trees and 4000 planting sites along its streets (City of Chico, 2010). These street trees create a significant sense of place in Chico, and they are recognized as a key component of the community design element. Since May, 2008, Scott Gregory has worked for the City of Chico to map and inventory the City's street trees. Gregory and Dr. Dean Fairbanks of CSU Chico, wished to use the inventory data to model the environmental services that Chico's trees provide. Project funding was provided by the CSUC Associated Students Sustainability Fund and by an internal CSU Research grant.

Using iTree Streets software, developed by the USDA Forest Service, in conjunction with ArcView v9.3.1, 2% of Chico's street segments were randomly selected. Street trees along those segments were field inspected, and species, height, diameter, presence of electrified wires, sidewalk lift, vigor, maintenance needs, and location were documented for 751 trees and planting sites using ArcPad 7.1 The resulting database was processed using iTree Streets to quantify the annual value of environmental benefits provided by the City of Chico's street trees.

Model output revealed that Chico's street trees currently store 42,980 metric tons of CO_2 valued at $710,656, and annually sequester an additional 1512 metric tons of CO_2, valued at $49,338. Chico's urban forest also annually provides $556,696 in energy savings, $412,200 in air quality benefits, and $223,693 in storm water reduction services. iTree Streets was also used to explore the projected benefits of alternative species composition scenarios relative to those of the current tree species distribution. By using iTree Streets to theoretically replace the City's decay-prone Silver maples with Japanese zelkova trees, the value of environmental services provided increased by $41,700 annually.

Chico's street trees are an integral element in calculating the City's carbon budget. In tight economic times, it is common for municipalities to cut urban forestry budgets. It is our hope that iTree modeling can provide a gentle reminder to administrators of the importance of preserving funding to maintain Chico's urban forest. We also aim to assist in advising Chico's future urban forestry management decisions to increase urban forestry benefits while streamlining maintenance costs.

MORE INFORMATION:
Scott Gregory
Dean H.K. Fairbanks
Department of Geography and Planning
California State University, Chico



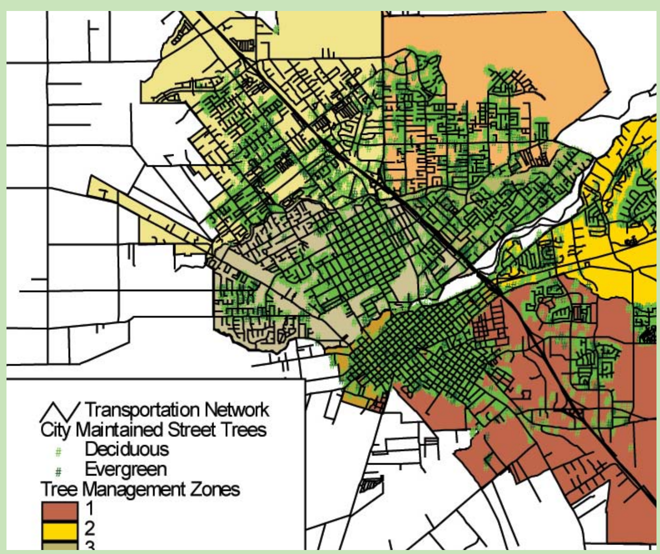


Photo Top Left: Scott Gregory collecting data in on the streets of Chico.
Above: Chico tree management map
Bottom: Detail from Geocoded Street Trees of Chico map

GIS Commons

Sacramento

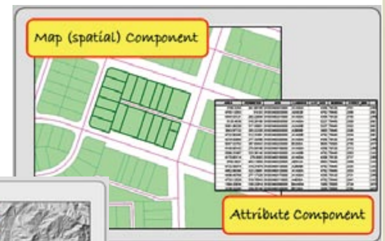
Introducing GIS Commons, A Free, On-Line Textbook

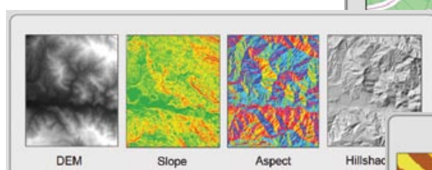
After about five years of writing and development, GIS Commons: An Introductory Textbook on Geographic Information Systems is available on-line (http://giscommons.org). GIS Commons is not a typical GIS textbook; it is a free, open-source, e-text that helps students, agencies, and organizations understand basic GIS concepts, analyze spatial data, and communicate more effectively.

At the heart of the textbook's development are two goals: The first goal is education. Making good maps is challenging and time consuming, but a new set of free and inexpensive mapping tools has enabled almost anyone with a computer to make maps. These maps, however, are often improperly designed and do not communicate easily nor effectively. GIS Commons seeks to educate its readers on how to create, analyze, and produce maps using GIS.

The second goal is to reduce textbook costs. Textbooks that focus on GIS concepts are frequently expensive. GIS Commons is free. GIS Commons is designed to benefit all sorts of students from typical college students who want to take geographic technology courses but have difficulty affording books to government agencies and non-profits organizations, also pressed for cash, which want to communicate effectively using maps.

MORE INFORMATION:
Michael Schmandt,
Department of Geography
Sacramento State University
schmandt@csus.edu





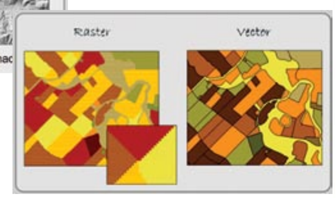


Figure 1: Sample of illustrations from the GIS Commons on-line textbook.

CSU Geospatial Review
CSU GIS Specialty Center
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132