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California Habitat Connectivity and Wildlife Movement Studies

Fragmentation of wildlife habitat, especially corridors of migration is a critical concern worldwide. The U.S. has been extensively fragmented through development of agriculture, mining and urbanization, and concerns have led to the passage of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), signed on August 10, 2005. This act authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 5-year period 2005-2009, and includes the provision that highway projects "reduce vehicle-caused wildlife mortality while maintaining habitat connectivity."

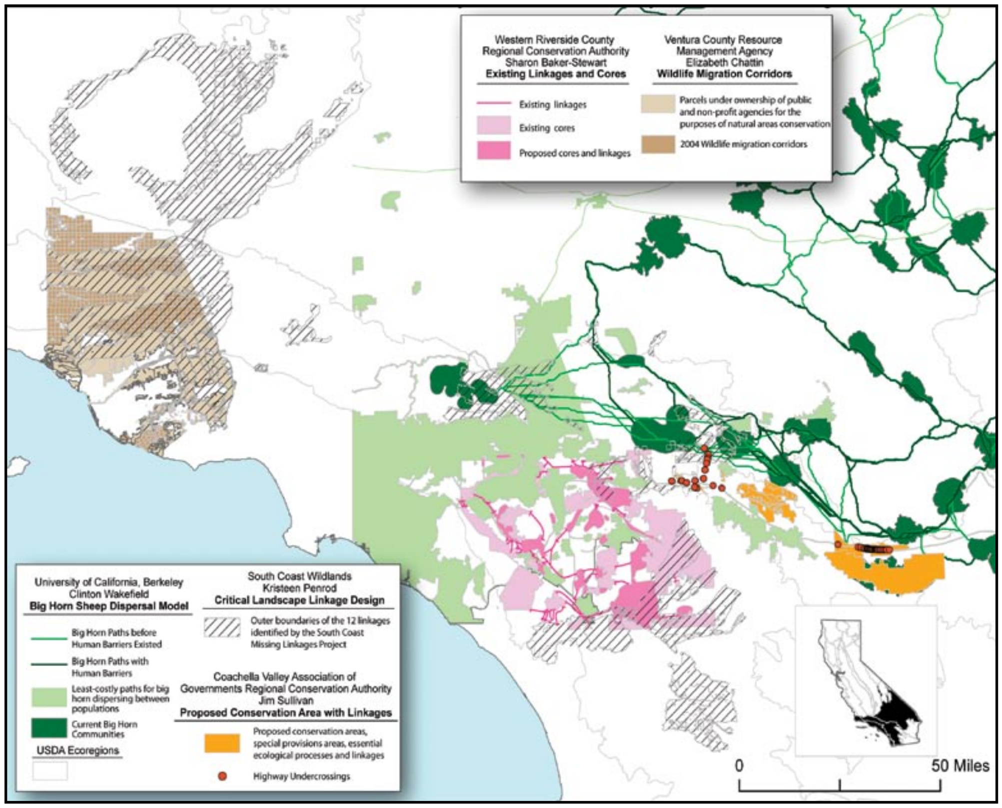

Figure 1: Corridor Studies in the Southern California Coast, Mountains and Valleys and Colorado/Mojave Desert Ecoregion. One of five regional and state maps created for the study.

To ensure compliance with this provision, Caltrans and California Department of Fish and Game selected SFSU's Institute for Geographic Information Science to compile existing research on wildlife movement and habitat fragmentation, using data provided by multiple agencies and universities around the state. This baseline information will be used by Caltrans, Division of Environmental Analysis and other agency staffs to help facilitate efficient and economical implementation of transportation activities. Synthesis of this information will also help to validate habitat and wildlife connectivity models. The study identified data gaps and identified minimum metadata field requirements for collecting future assessments, monitoring information and tracking information pertaining to wildlife movement and habitat connectivity.

Agencies and organizations represented in the compilation included California Department of Fish and Game, The Nature Conservancy, California Wilderness Coalition, UC Davis, UC Berkeley, South Coast Wildlands and a number of regional management agencies. A total of 69 animal species and 26 plants were identified as part of all studies compiled, including 5 amphibians, 8 reptiles, 16 birds, 5 fish, 6 insects, and 29 mammals. Study types were grouped as:

- Preserve Areas (26% of studies) with a network of habitat and open space
- Corridors (57%) of animal migration
- Barriers (4%), primarily to salmonid migration
- Habitat/Distribution (11%)
- Road Kill (2%).

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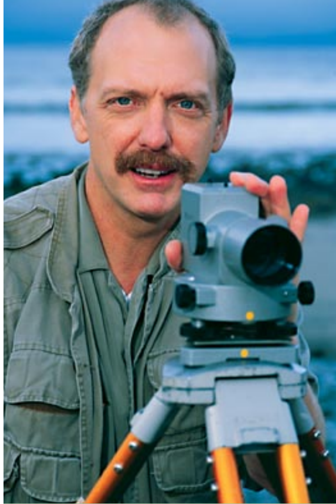

Lean times and opportunities

THE CALIFORNIA STATE University is currently undergoing a great deal of belt-tightening as a result of the state's budget problems. It's an easy time to get depressed as we see students having a harder time getting into fewer class sections. In the GIScience arena, we're faced with less frequent computer hardware upgrades from general fund sources, so we're all having to get creative about how to maintain an appropriate level of excellence in our instructional methods that rely on technology.

Yet there are opportunities. The federal stimulus plan provides significant investment in technological development and scientific advancement. The NSF and NIH grant programs have each received major boosts, and GIScience can contribute to the needs they are intended to support. Our community certainly understands that intelligent uses of natural resources is a major part of economic health, and GIS and remote sensing methods are important part of that intelligence.

So instead of retreating to our holes and waiting for better economic times to return, we should be a vital part of the solution. We are fortunate to be in a good position to contribute to advanced research in geospatial analysis of health and natural resource geographies that should not only advance societal needs but also be able to attract significant funding.

When life gives you lemons, make lemonade.

Jerry Davis, *Director,* CSU GIS Specialty Center
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Habitat Connectivity (cont.)

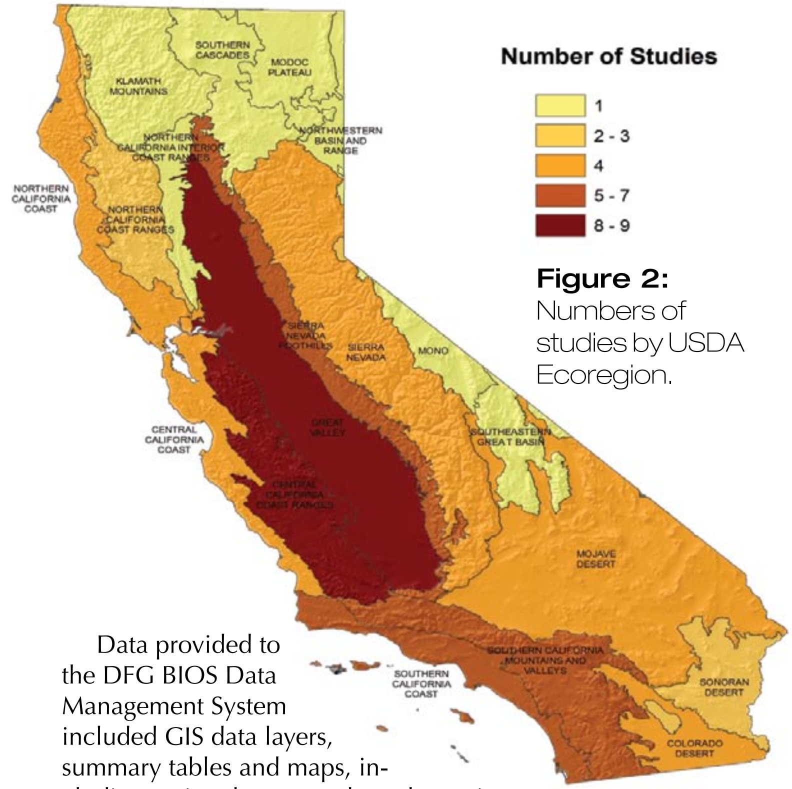

Figure 2: Numbers of studies by USDA Ecoregion.

Data provided to the DFG BIOS Data Management System included GIS data layers, summary tables and maps, including regional maps such as shown in the example map (fig. 1). Coverage depended on agency personnel providing data, which was good for the central valley, southern California, but sparse for the Sierra Nevada, Klamath Range and northeastern California (fig. 2).

In conclusion, while it is clear that considerable study has been made of habitat connectivity patterns in California, the current status demonstrates that there is much we do not know and have not studied. There are many challenges, especially with less visible organisms such as amphibians. Many important habitat areas, including major mountain ranges -- Klamath, Cascades and Sierra Nevada -- and wide swaths of northern and eastern California, are understudied. It is worthy to note that the Klamath Range includes some of the highest diversity of conifer species in the nation. Meadow and desert environments of the eastern and northeastern regions of the state also include biodiversity hotspots.

California is well known for its natural diversity, and this can be seen in the large number of endemic plants and animals in the state. Yet habitats protected in nature reserves are increasingly fragmented, a problem that will only increase with the effects of global climate change. Added to an increasing potential for interruption of corridors by road networks, increasing our understanding of these corridors demands attention by academics and agency personnel.

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GIS in Integrated Water Management Planning

Increasing attention to California's water resources has brought renewed emphasis on collaborative management practices. While there are severe problems facing the state and many fracture planes in the public interest that weigh against quick solutions, some progress gives hope for future broad solutions. Many federal, state and local agencies and private bodies have interests in water management. As noted in Chuck Nelson's "CalWaterMap: A GIS Tool for Small Water Agencies" (CSU Geospatial Review, Volume 6, Spring 2008) access to basic Geographic Information Systems (GIS) technology is not evenly distributed.

GIS is seen by many as a key integrating technology to help assemble and organize data, analyze those data and feed into the decision-making process. Water management planning is increasingly a regionalized approach. This can be seen at California Department of Water Resources' website;

> *"The Integrated Regional Water Management (IRWM) Program is intended to promote and practice integrated regional water management to ensure sustainable water uses, reliable water supplies, better water quality, environmental stewardship, efficient urban development, protection of agriculture, and a strong economy. See* California Water Plan Update 2005 Bulletin 160-05.*"*

California State University Fresno's California Water Institute (CWI) has been working under a grant from Governor Schwarzenegger's Partnership for the San Joaquin Valley to facilitate Integrated Water Management Planning throughout the eight counties from Kern in the south to San Joaquin in the north. CWI staff works with water interests to build collaborations. A major task has been to try to identify who those various interests are and to determine which areas have stewardship plans in place or in planning or not yet started.

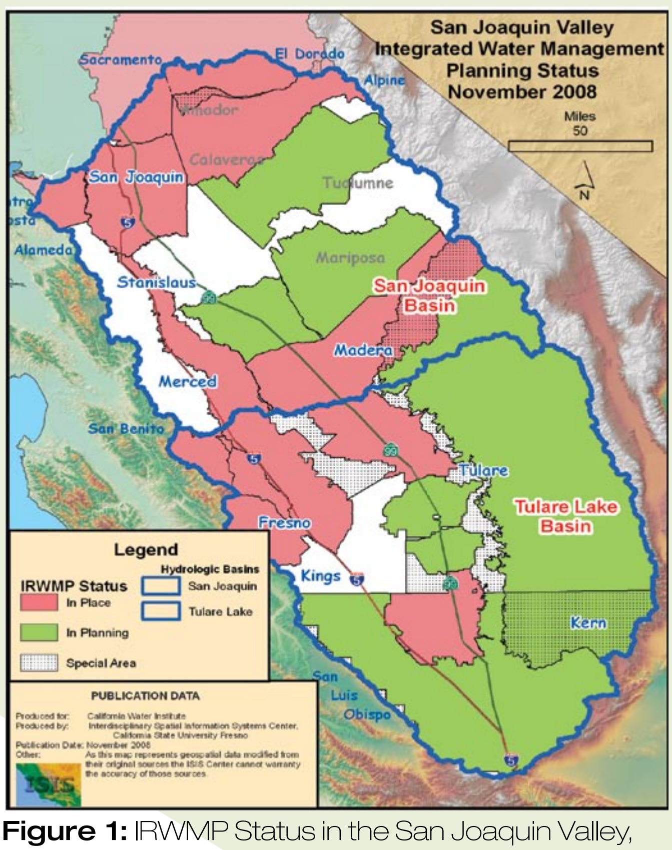

Figure 1: IRWMP Status in the San Joaquin Valley, November 2008. The white areas have no recognized IRWMP in place or in process.

The University's Interdisciplinary Spatial Information Systems Center has identified, assembled and assessed geospatial data sets useful in the water planning process. The ISIS Center supports the IRWMP process by assembling an inventory of participants and through some preliminary thematic mapping (Figure 1).

Groundwater storage is a major component of water management in the San Joaquin Valley. As urban areas expand and cover soils suitable for groundwater recharge, soil characteristics will become an important component of urban planning (Fig. 2).

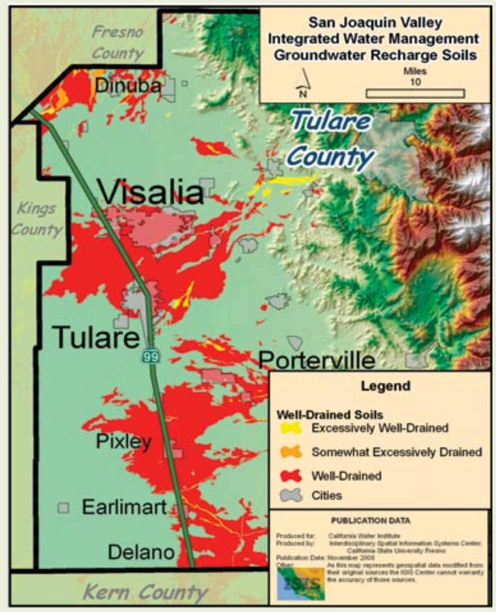

Figure 2: Tulare County Groundwater Recharge Soils. The well-drained soils are located along the major development corridor.

A GIS-based website runs off the CWI home page www.californiawater.org to assist local water planners.

In addition to the water planning efforts, CWI director, Dr. David Zoldoske, is leading a CSU initiative to move more aggressively into the California water arena. *"Under the leadership of Chancellor Reed, the California State University (CSU) has identified the area of Water Resources and Policy Initiative as a system wide opportunity for academic excellence and student success. Given all the issues currently facing California, water rises to the top as perhaps the single most important concern."*

GIS is a great integrating tool, one that fosters collaboration among its practitioners. The movement of GIS utilization up the decision-making chain in California is important for a comprehensive approach to water management.

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Humboldt

Bathymetric Mapping

In July, 2008, Humboldt State graduate student, Brian Huggett, and a small team of hydrology technicians were dispatched to Yosemite National Park's remote, alpine region to collect lake sediment samples for the purpose of pesticide analysis. The team carried a GPS unit and handheld depth sounder to record the location and the depth of the sediment samples. Once the necessary sediment samples were collected, the team realized that they could also produce a bathymetric map of the lakes by combining the two technologies. The team capitalized on this 'measurement of opportunity' to create the first map of its kind for lakes in the high Sierra.

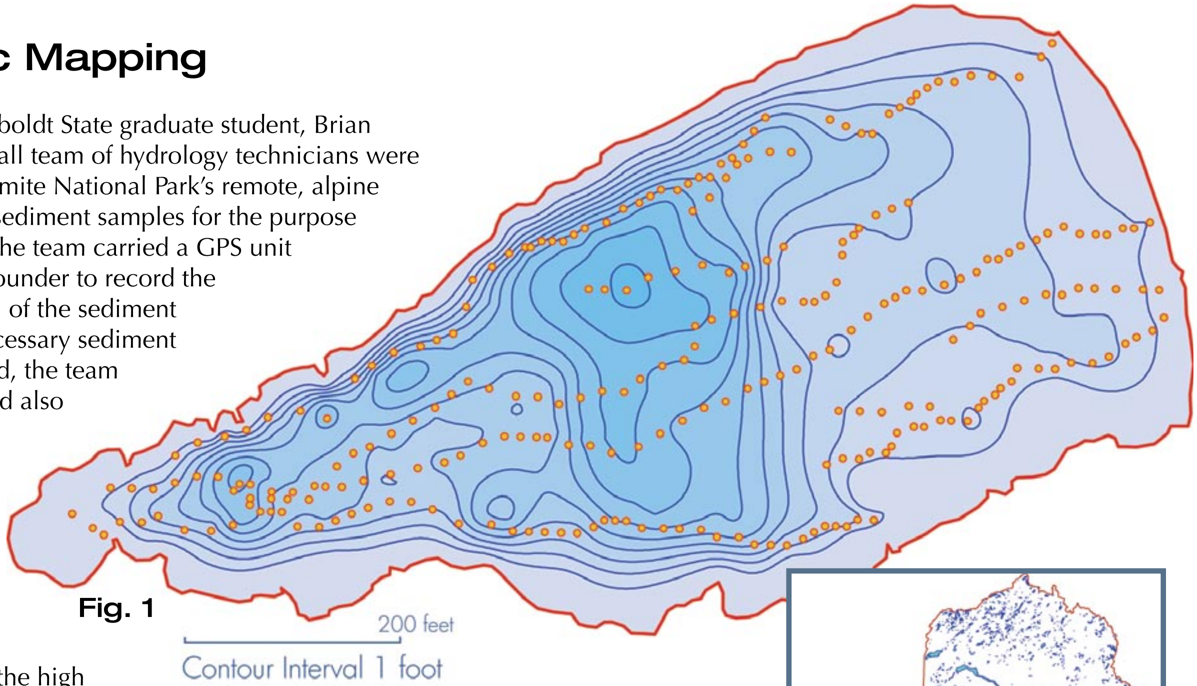

Fig. 1

Bathymetry is the measurement of depths in a body of water. Historically, the term referred to measurements made in the ocean, but within the last hundred years the term also came to encompass mapping depths in freshwater lakes. The earliest, and most reliable, method for measuring depth involved nothing more than a calibrated rope and weight tied to one end. As time and technologies progressed, traditional surveying methods complimented the depth measurements and the production of accurate bathymetric maps were born. Recent methodologies have used the Global Positioning System and sonar technologies to create dense networks of XY and Z points, from which Triangulated Irregular Network (TIN) models or interpolated surfaces could be generated. Important limnological characteristics, such as volume, or hypsography—the distribution of lake area versus depth, can be derived from such data sets and are used by hydrologists. Agencies like the United States Geological Survey and universities like the University of Wisconsin–Eau Clair, have led the way in developing these methods on easily accessible reservoirs and lakes using motorized boats to carry the large amounts of equipment. The method of bathymetric mapping described here builds on these established methods, but differs slightly in the technologies used and largely in the locale and type of environment mapped.

Having recently completed Humboldt State's GIS and Remote Sensing Certificate, Huggett understood that joining the two data sets could be accomplished in a GIS, based on a common attribute. The two data streams would share the attribute of time; hence the GPS unit was set to collect waypoints every 15 seconds, and using the unit's clock, a depth was sounded every 15 seconds and transcribed into a field notebook. With the light westerly breeze blowing, the technician was blown to the far side of the lake collecting XY and Z data. Upon reaching the other side, he paddled back to repeat the process 3 more times. In 2 hours, he collected over 280 data points on the 8 acre lake. Later in the lab, with the field notes transcribed into digital format, the XY and Z data

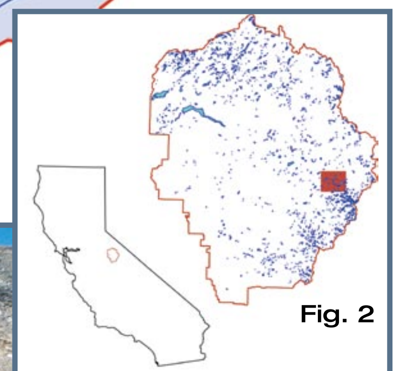

Fig. 2

Figure 1: Bathymetric map of Fletcher Lake, Yosemite National Park
Figure 2: Yosemite National Park study site in red box. Yosemite has over 3,200 lakes and ponds.

were joined, the lake bottom was interpolated with contours generated to provide the familiar look of topographic maps.

While this method opens up bathymetric mapping to remote locales, it does suffer slightly from accuracy issues inherent in the consumer GPS unit. This issue is readily solved by using a GPS unit that is capable of differential correction. Ultimately,this low cost method can serve as a blueprint for further hydrologic research that has an inherent geospatial nature, such as bathymetric mapping.

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2009 COMING EVENTS

June 22–23, 2009
University Consortium for GIS (UCGIS)
Summer Assembly, Santa Fe, New Mexico
http://www.ucgis.org/

July 13–17, 2009
Twenty-ninth annual ESRI International User Conference
San Diego Convention Center, San Diego, California
http://www.esri.com/events/uc/

July 18–21, 2009
Society for Conservation GIS (SCGIS)
Annual International Conference
Northwoods Resort and Conference Center
in Big Bear Lake, California
http://www.scgis.org

April 12–16, 2010
AAG Annual Meeting, Washington, DC
http://www.aag.org

GIS users will gather June 13-17 in San Diego, CA to connect, learn, and share at the 2009 ESRI UC.

What is Geographic Information Science (GISci)?

GEOGRAPHIC INFORMATION SCIENCE is the synthesis of spatial theory, methods and technologies used to study and map geographic relationships, distributions, networks, temporal change and other spatially aware information in order to better understand and manage limited earth resources. It includes:

GEOGRAPHIC INFORMATION SYSTEMS (GIS) Comprehensive databases tied to location, with an integrated set of tools for querying, analyzing, and displaying information. Important classes of GIS tools include those that support: (1) logical map overlay, (2) proximity analysis and spatial buffering; (3) network analysis (e.g. of roads or streams); (4) geocoding and address matching; and (5) three-dimensional surface modeling.

REMOTE SENSING
Analysis of the earth's surface and interpretation of its features using imagery collected from air or space platforms. Image processing methods use visible and invisible (e.g. ultraviolet and infrared) parts of the electromagnetic spectrum as well as active radiation (RADAR and LIDAR) to interpret land cover patterns of vegetation, soil, land use, and environmental systems, including up-to-the-minute changes in these systems.

CARTOGRAPHY
The art and science of making maps. Cartographical theories and methods focus on information content, symbolization and design to appropriately communicate the results of studies.

GLOBAL POSITIONING SYSTEMS (GPS)
Provides a means for determining earth location and navigation, using a constellation of satellites and the technology for interpreting their signals. Field data collection for GIS and remote sensing projects is increasingly dependent on GPS.

WHILE HAVING ITS ROOTS in geography, many disciplines have contributed to the development and use of Geographic Information Science. In the CSU System, anthropologists, biologists, business marketers, computer scientists, economists, engineers, environmental scientists, foresters, geologists, historians, journalists, landscape architects, natural resource planners, oceanographers, political scientists, sociologists, urban planners, and wildlife scientists also use these technologies in their classes and for their research.

Mapping land-use/land-cover change in the Dry Chaco ecoregion of Argentina, Bolivia and Paraguay

Figure 1: Soybean farming has replaced forested areas.

Dr. Mathew Clark at Sonoma State Univ. and colleagues have funding from the National Science Foundation (#0709598) to explore how economic globalization is affecting land-use patterns in Latin America and the Caribbean (LAC) through an analysis of ecological, demographic and socio-economic geospatial datasets. A key component of this analysis is to map annual land use/land cover (LULC) from 2001 to present across all of LAC using images from the NASA's MODIS sensor. Here we report results from our "test-bed" area, the Dry Chaco ecoregion of southeastern Bolivia, northwestern Argentina and western Paraguay. The region includes large areas of tropical dry forest. In wetter areas, recent deforestation has been driven by mechanized soybean production to serve rising demand from China and Europe (Fig 1). Drier regions have experienced forest degradation due to cattle grazing.

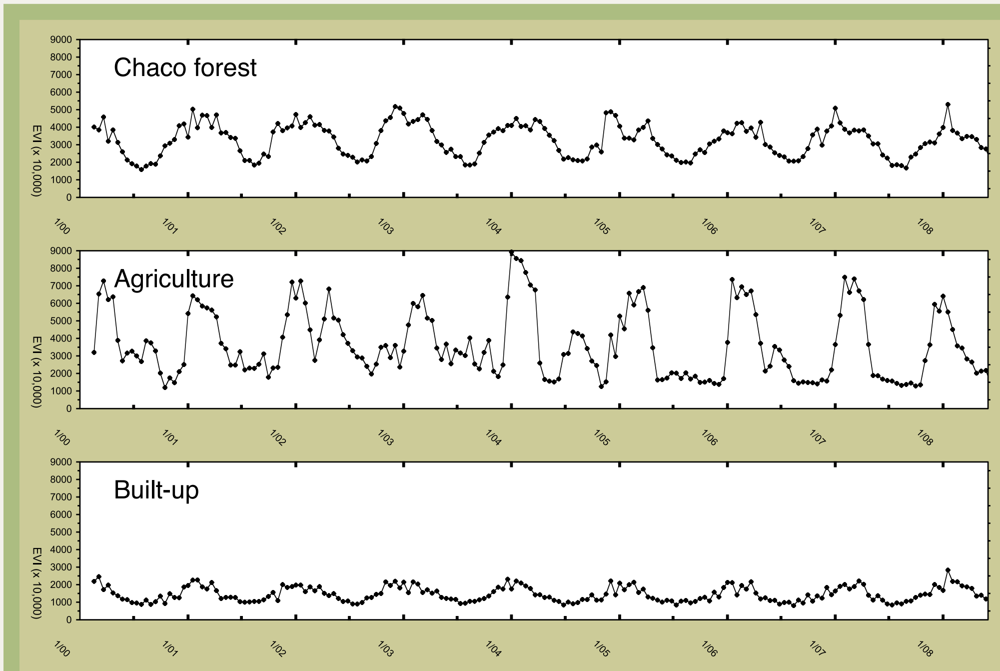

Figure 2: Tracking EVI patterns through time.

Our classification method uses the 250-meter MOD-13 MODIS product, which provides blue, red, and near-infrared (NIR) reflectance and Enhanced Vegetation Index (EVI) data composited from the highest-quality pixels over a 16-day period. Natural vegetation and human land-use classes have different EVI temporal patterns that reflect the seasonality of leaf production and loss—or phenology—in the pixel over time (Fig. 2). For example, Chaco forest has drought-deciduous plants that produce leaves in the wetter months of the South American summer, creating a peak in EVI at the height of the growing season. In drier winter months, the plants lose their leaves, causing relatively low EVI values (Fig. 2, Chaco forest). In contrast, an area with mechanized agriculture may have 2 growing seasons per year with two annual EVI spikes (Fig. 2, agriculture). A built-up area, with many roof-tops and roads, has relatively low EVI values throughout the year, but still reveals a phenological signal due urban vegetation (Fig. 2, built-up).

We used the TIMESAT (Jönsson and Eklundh, 2004) time-series analysis tool to derive phenological variables from the EVI data. This program fits a polynomial function to the raw EVI data, down-weights pixels with low reliability, and reports the following variables for each growing season (Fig. 3): a) start, b) middle and c) end day of season, d) length of season, e) base value, f) maximum EVI value, g) amplitude, h) left derivative of season curve, i) right derivative of season curve, j) integral (area) of season relative to the base value, and k) integral of season relative to zero. MODIS data was also processed to provide annual mean, standard deviation, minimum, maximum and range of red and NIR reflectance and EVI.

Our ultimate goal is to produce thematic maps of LULC for each year over all of LAC. We thus needed reference data that 1) cover the whole region, 2) are produced in a consistent manner, and 3) are cost-effective to collect in terms of time and money. The availability of high-resolution Quickbird images in Google Earth provided us with free access to thousands of images that we could use for detailed visual classification. We first generated random reference points with a corresponding 250 x 250 m grid for viewing in Google Earth. Within each grid, two students estimated the percent cover of woody vegetation, herbaceous vegetation, crops, plantations, urban areas, barren areas, and water. When students disagreed on the majority class, the point was then sent to an "expert" for review. We collected 1664 Dry Chaco reference points using this process.

We used Random Forests (Brieman, 2001) for image classification. This relatively new technique generates multiple decision tree classifiers from random sampling of the reference data. A final class is determined from the majority vote of the "forest" of decision trees. Reference samples withheld from a tree in a given iteration are used to estimate classification accuracy. We implemented the Random Forest classifier using the R statistical program and a custom program designed in the Python language. The TIMESAT phenology and annual statistics variables were extracted for the year matching the image date in Google Earth, and these data went into generating a random forest. Finally, the random forest was then applied to image stacks to yield annual LULC maps from 2001 to 2007. As new MOD13 data comes online, we can easily produce up-to-date maps.

An example classification for part of the Dry Chaco is shown in Fig. 4. From 2001 to 2007, there was in-filling of agriculture around wetter areas already deforested in the west and agriculture expansion toward the drier east. The overall accuracy for this classification was 80%, with the majority of class confusion occurring between herbaceous and cultivated areas . These areas were also difficult to distinguish visually in Google Earth, and so reference data errors explain part of the class confusion. In the coming months, we will work to refine our LULC classification methodology and expand processing to other LAC ecoregions.

Breiman, L. (2001). Random Forests, Machine Learning, 45, 5–32.
Jönsson, P & Eklundh, L. (2004). TIMESAT—a program for analyzing time-series of satellite sensor data. Computers & Geosciences, 30, 833–845. D

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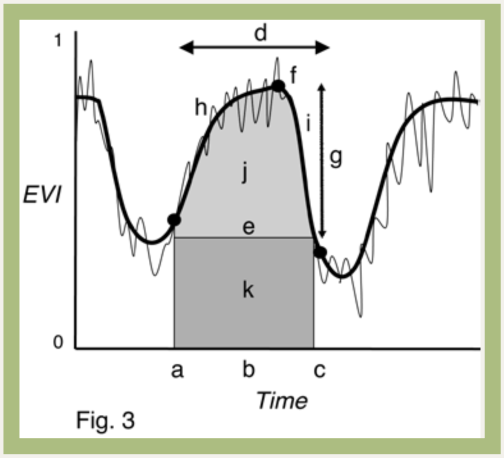

Figure 3: Results from TIMESAT time-series analysis.

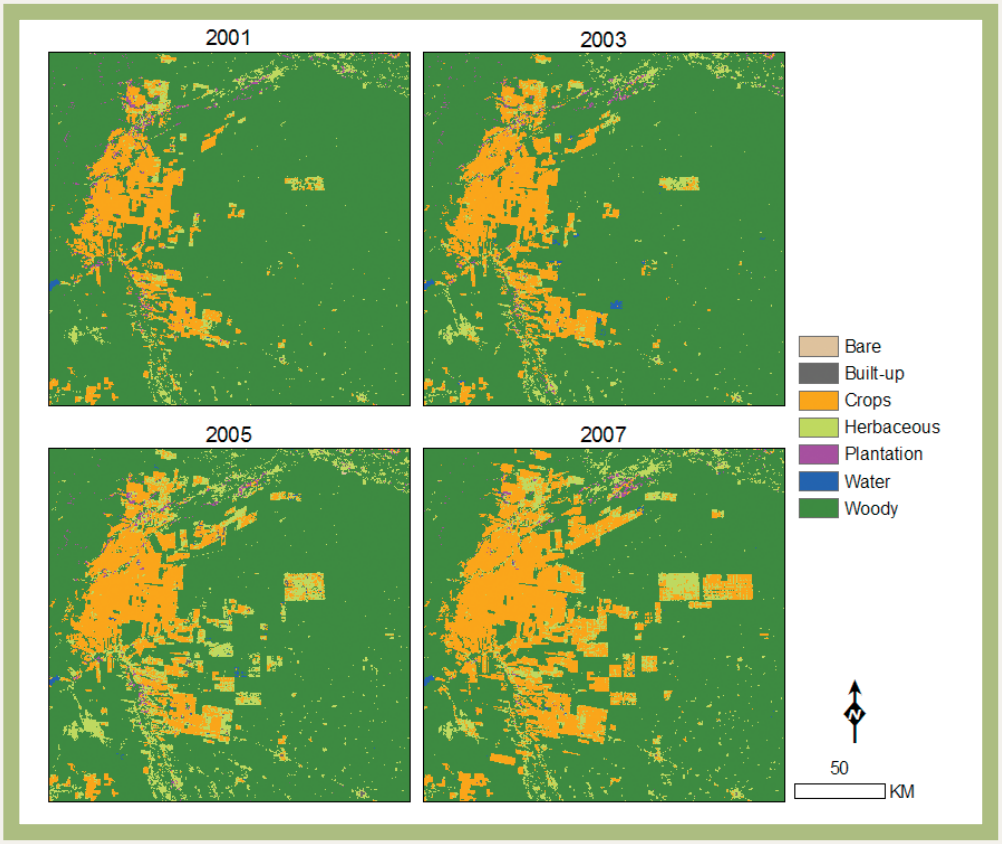

Figure 4: Land use classification of the Dry Chaco.

Cal Poly Pomona CGISR Developing Plant Atlas GIS Data Model

The Center for Geographic Information Science Research at Cal Poly Pomona is developing a protocol and software tools for building digital plant atlases in GIS. Geography Professor Michael Reibel and CGISR Program Administrator Boykin Witherspoon are developing the protocol with support from and in collaboration with the Huntington Botanical Gardens in San Marino, which received a grant from the Boeing corporation.

The data model under development is designed for volunteers or students to enter the locations of specific trees and other key plant species in a defined monitoring area using GPS. The data are then captured and managed in a GIS for analysis and cartographic purposes.

In collaboration with the city of Pasadena, the Huntington Botanical Gardens and the CGISR plan to initially implement the protocol and build a plant atlas for that portion of the Arroyo Seco watershed that lies within the city boundaries. The Arroyo Seco project is expected to incorporate a training component for Cal Poly Pomona GIS students.

Once the data model and GIS tools are developed and tested, they will be available for collaborations with other agencies or institutions wishing to monitor plant life in a defined area. In addition to providing access to the tools and protocol under terms to be determined, the CGISR will have the ability to manage plant atlas data and relevant baseline data and to provide analytic and cartographic services.

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