April 2013

GIS in Africa 2

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What Is GIS?

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

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

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

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

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

GIS Helps Fight World's Leading Cause of Preventable Blindness

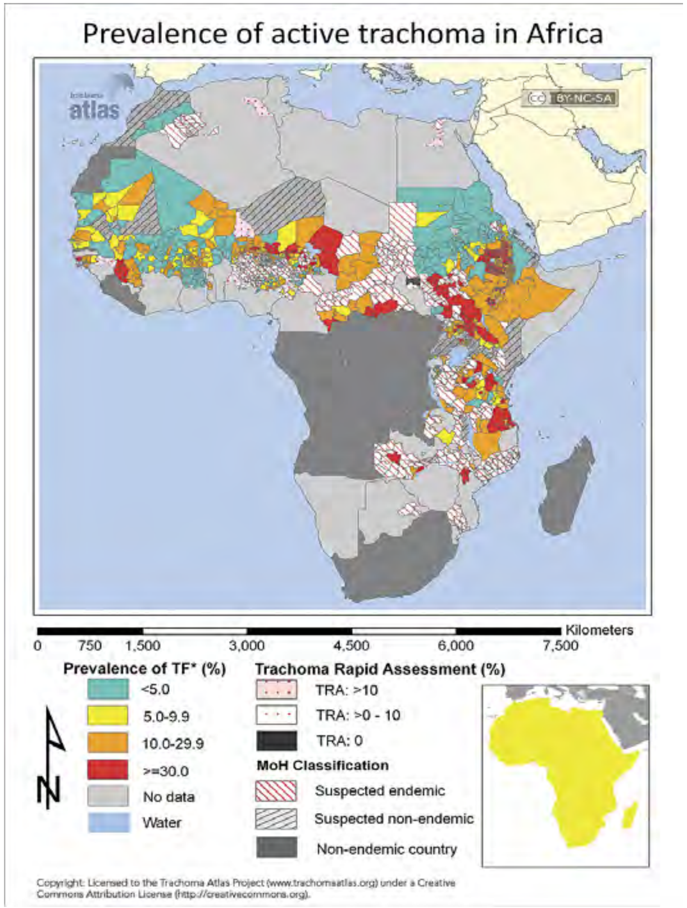
Tracking the Global Distribution of Trachoma

It feels like thorns scraping your eyes each time you blink.

Repeated infections during your childhood lead to scarring of the conjunctiva, or inner mucous membrane of the upper eyelid. Your eyelashes turn inward and scratch the cornea. Slowly, painfully, you may go totally blind.

The affliction is called trachoma, and it affects mostly women and children among the poorest of the poor, especially in regions that have limited access to sanitation and water. There are more people suffering from trachoma in Africa than on any other continent. And because this bacterial disease is transmitted via close, personal contact, it tends to occur in clusters—often affecting entire families and communities.

Approximately 110 million people worldwide live in endemic areas and require treatment, with 210 million more living where trachoma is suspected of being endemic, according to International Trachoma Initiative (ITI) at Task Force for Global Health, based in Decatur, Georgia.



This map of Africa from www.trachomaatlas.org illustrates the known distribution of trachoma and the data gaps across the continent.

"Affected people are said to be living beyond the end of the road," says Dr. Danny Haddad, director of ITI. "In some instances, you need to walk half a day to get to some of these villages."

Neglected No Longer

Until recently, a better means to identify enclaves of a rogue's gallery of so-called neglected tropical diseases—such as leprosy, river blindness, roundworms, elephantiasis, African sleeping sickness, and trachoma—has proved elusive.

Fortunately, according to Haddad, researchers combining smartphone and Esri technologies have figured out a quick way to visually assess the prevalence of trachoma in remote regions and pinpoint gaps in prevention and treatment services.

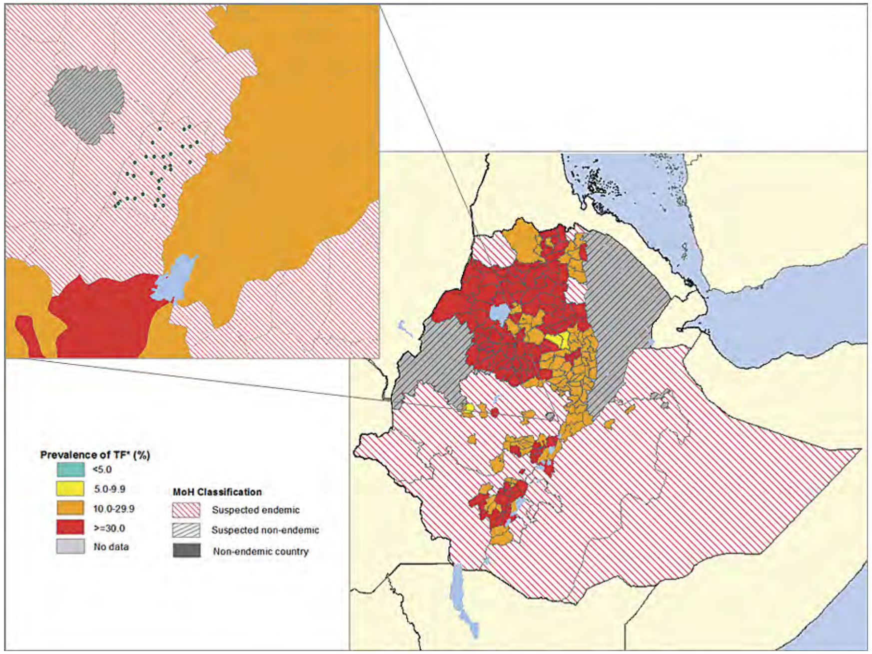
A trachoma developmental study of the latest data collection, transfer, and visual display process using ArcGIS began in mid-October 2012 in the Oromia region of Ethiopia. Several layers of smartphone and Esri technology enabled the immediate transfer of vast amounts of collected data to distant hardware and software platforms for data display, analysis, and sharing.

Esri software was chosen because of its dynamic capabilities, says epidemiologist Alex Pavluck, a senior manager of research information technology at ITI. Not only are GIS maps useful as visual tools, but they also offer real-time transfer of data and automated updates that provide much-needed efficiencies.

"One thing we wanted was the ability to produce layered maps," Pavluck says. "These are really the key here to show prevalence overlaid with areas currently receiving treatments, such as donated drugs."

The goal was to help realize an ambitious plan endorsed by World Health Organization (WHO)—a dream, if you will, of endemic countries with organized national trachoma control programs—called Global Elimination of Blinding Trachoma by 2020, or GET2020.

According to Haddad, the Esri technology-enhanced system was built on one already developed for a variety of neglected tropical diseases, including trachoma. It relied on Android devices, which made it easy for field-workers to use. A robust reporting back end allowed data to be sent via cellular network or Wi-Fi to a web-based system at Task Force's headquarters. It didn't take long for this approach to achieve surprising results—transmitting data from 18 countries on elephantiasis.



The point features generated by the Esri Python script can be aggregated to the health district—turning the health district classification from "suspected endemic" to a prevalence value. This knowledge drives health interventions.

"Before we used the Android tools, we had piles of paper that had to be manually entered after a survey," recalls Haddad. Initial success encouraged public health workers in endemic countries to realize that a system such as this—but even more capable—was needed to reach WHO's ambitious GET2020 goal.

Global Atlas of Trachoma—developed in 2011 by ITI with the support of partners, such as the Bill & Melinda Gates Foundation, Carter Center, and London School of Hygiene & Tropical Medicine—provided up-to-date regional maps of trachoma's geographic distribution. This tool allows health workers to reach more people with preventive hygiene, corrective surgery, and an antibiotic—azithromycin (Zithromax)—donated by pharmaceutical manufacturer Pfizer Inc.

Nevertheless, researchers discovered that the database supporting the atlas identified more than 1,200 health districts that still lacked the data needed to guide interventions. "We still didn't have the entire picture," says Rebecca Mann, geographic information systems data manager, ITI.

Heart of the System

The latest Esri software-enhanced system is designed to correct that. Here's how it works: Trained field-workers initially collect data on smartphones and tablets using Android technology. "That's the beauty of it," says Mann. "The app can go on any device running Android."

Then, the devices quickly transfer data to a website on a server housed at the Task Force in Decatur, where it is summarized, checked for errors, and mapped. Using a 3G connection, the data can be transmitted to the server in real time.

Next, the data moves to a central MySQL Server linked to an ArcGIS mapping server. Python script automatically converts tabular data into feature points that link to ArcGIS map templates embedded in a project website on arcgis.com. These points accumulate on the web maps as data is collected, illustrating the distribution of surveyed clusters and ensuring selected samples spatially represent the entire survey area. The server makes the data widely accessible to researchers and managers worldwide, who then can review the accumulating information in real time and approve it for wider dissemination, such as in the trachoma atlas.

ArcGIS for Server pushes the data onto more detailed maps that show the entire survey area, providing visual displays that aid health workers in more quickly identifying affected areas and people needing treatment.

A health care worker collects data using a smartphone.

"It was nice that we didn't have to reinvent the wheel," says Esri Professional Services applications developer Danny Hatcher, who set up the servers and wrote the Python script. "We could fit hand in glove with the existing process and turn it into a map ITI could use."

Proof of Concept

Mann recalls her excitement when the Ethiopian developmental study began. Pavluck needed just half a day to train a team of local field-workers how to use the smartphones.

"Because the system is so simple, it isn't necessary to train a highly specialized team," Mann says.

When the field-workers in Ethiopia started collecting data, Mann and colleagues in Decatur could actually see it flow from the phones to their server.

"Python script ran at 2:00 a.m. every morning, converting the data into feature points, which I personally added to the first mapping template," Mann notes. And as more data came in, the system automatically updated the website.

The researchers plan to add features if the system runs smoothly. "As we get into the rhythm of things, I'm sure we'll want to tweak our system," Mann says. "But right now, we're trying to keep it as simple and straightforward as possible."

Haddad says researchers are looking at other neglected tropical diseases and, thanks to GIS, can more clearly see gaps in defenses against them. "This system is making a huge impact on how we run our programs," he says. "It allows us to make much faster decisions on what we need to do."

For more information, visit www.taskforce.org, www.trachoma.org, www.trachomaatlas.org, and www.trachomacoalition.org.

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Creating a National Park from the Bottom Up

The Democratic Republic of Congo's Lomami National Park and GIS

Three rivers surround 40,000 square kilometers of mysterious forest in the heart of the Democratic Republic of Congo (DR Congo). Until very recently, it was unexplored. It has no airstrips; its paths are without bridges. No four-wheel vehicles can come even to the sparse settlements, which are limited to the area's periphery. In 2007, an expedition—made up of conservationists with experience from exploration and wildlife inventory in other parts of DR Congo—entered this forest situated between the basins of the Tshuapa, Lomami, and Lualaba Rivers. The TL2 project, as it is now known, was led by Lukuru Foundation researchers John and Terese Hart, who set out to survey large mammals and human activity and now are promoting the creation of a protected area in this, one of the world's last unexplored tropical forests.

The TL2 project mission is to build effective conservation, from a village base to national administration. It is a locally based project, built on the diplomatic and field experience of the Harts and a cadre of Congolese field biologists with whom they had worked on previous projects. More and more local people have joined the project, bringing the advantage of long experience in the forests, languages, and cultures of the TL2. Their combined observation and diplomatic skills are critical for the scale of coverage and tying results together to give the products needed for enduring conservation. Since 2007, these teams have

The lesula monkey (*Cercopithecus lomamiensis*), a new species of monkey documented by TL2 project researchers in the middle of Lomami National Park.

surveyed the forest by walking over 5,000 kilometers of compass-directed inventory tracks.

From the beginning of their surveys, the Harts sought GIS support to explore; document; and, eventually, define the area for conservation. An innovative partnership was developed in 2007 with Canadian Ape Alliance, a nongovernmental organization based in Toronto, Canada. Nick January, a volunteer GIS application specialist with the alliance, directs the collaboration with Lukuru's TL2 project through an Esri Conservation Grant, which has been generously supported since 2005. Fully equipped with multiple ArcGIS for Desktop, ArcGIS Spatial Analyst extension, and ArcPad licenses, the Harts are now able to capitalize on an existing mapping system that documents, stores, analyzes, and provides end products in support of their conservation efforts.

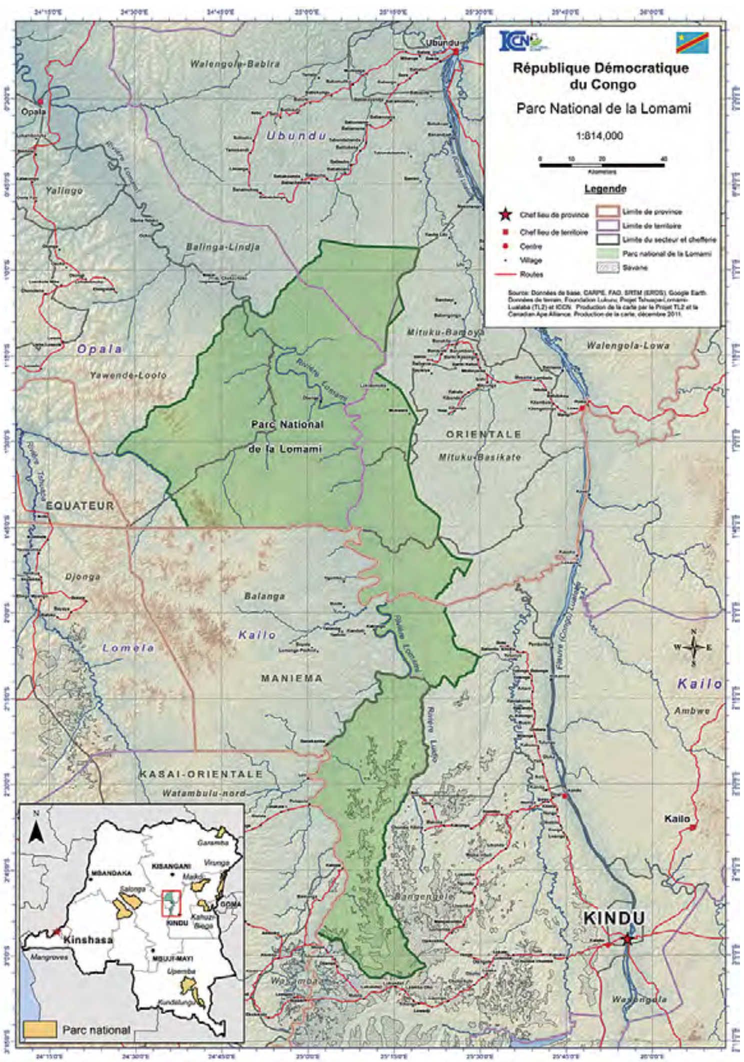
The development of an accurate and comprehensive basemap—an essential tool—was a daunting challenge. How could the TL2 teams accurately map a proposed protected area in such a remote and inaccessible region of central Africa?

It quickly became apparent that the available data was inaccurate and would have limited use for the scale of the TL2 project. For DR Congo, digital basemap data was restricted to widely distributed, publicly available national shapefiles (including transport, vegetation cover, river networks, political boundaries, protected areas, and elevation data). To successfully delimit the newly explored area, an early focus for the TL2 GIS was a complete overhaul of local geospatial data for the basemap.

GPS field data from multiple reconnaissance surveys was being rapidly collected and added to a growing volume of TL2 data (spreadsheets, databases, KML files, field notes). This stream of invaluable data was collected on the comprehensive and collaborative Lukuru/Canadian Ape Alliance GIS platform for TL2. The TL2 contributors learned a routine for documenting, storing, maintaining, editing, and analyzing the geospatial data so that final cartographic products would become more sophisticated and precise for what had recently been unexplored, inaccessible forest.

As TL2 field data became available, January worked on creating a more reliable basemap. To eventually get a delimited map of the proposed protected area, all map features needed to be digitized, including river networks, villages, and roads that had long since turned into footpaths. These were logical park boundaries. This background work included the use of Arc Hydro to create watersheds and drainage patterns, the incorporation of GPS field data to accurately map settlements, and the use of satellite imagery to further confirm location accuracy and content. Older maps and legal documents were used to correctly lay out internal political boundaries.

The Esri Conservation Grant expanded as the TL2 project added staff and ArcGIS expertise. Esri's technical and administrative



Proposed Lomami National Park, Democratic Republic of Congo.

support from both US and Canadian offices became critical to the GIS operation. Not only was a smooth integration and analysis of volumes of field data from a variety of sources possible but so too was a seamless transfer to web-based platforms, such as ArcGIS Online. With Esri software licenses and training materials, it was possible to have multiple installations under dispersed field working environments despite many hardware malfunctions.

In five years, the TL2 project has made important progress toward establishment of Lomami National Park. Exploration has led to the definition of boundaries for the remote park; these are delimited through the incorporation of GIS technology and Esri support. Surveys have resulted in previously undocumented populations of bonobo chimpanzees, okapis, elephants, monkeys, and Congo peacocks. One of the most important discoveries of the TL2 project has been the documentation and confirmation of a new monkey species living in the park area, the lesula monkey (*Cercopithecus lomamiensis*), an event that garnered international attention for the species, as well as Lomami National Park.

Once the park is officially established, the TL2 project will continue to monitor wildlife populations and hunting in the region. It will conduct conservation outreach programs in town centers, villages, and state capitals. The project will also train local people and students to protect, monitor, and promote conservation in Lomami National Park and in the DR Congo overall. With collaboration from the Congolese parks authority, outside experts will be able to visit and experience this extraordinary region and continue its exploration, documentation, and preservation.

For more information, visit bonoboincongo.com, www.bonoboincongo.com, or www.great-apes.com.

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Improving Service Delivery and Collaboration in South Africa

Named for one of South Africa's 20th-century democracy advocates, the Frances Baard Municipality District is situated in a mostly rural area of the country's northern central region. A sunny and semiarid climate and natural rivers make it a popular tourist destination for bird-watchers, hunters, and photographers. The region is well known for its agriculture, with exports of fruit and vegetables, as well as mining activities.

The Frances Baard Municipality District includes mostly rural areas of South Africa's Northern Cape province.

While Frances Baard is the smallest district in the Northern Cape province, it's actually the most populous of the Northern Cape districts, with nearly 325,000 citizens spread through the local municipalities of Sol Plaatje, Phokwane, Dikgatlong, and Magareng.

Like all municipal districts in South Africa, officials for Frances Baard are charged with assisting local municipalities in carrying out the basic functions of local government. Responsibilities include promoting social and economic development while delivering basic services, such as water, electricity, waste removal, and health care. Frances Baard must also carry out integrated development planning for the district, which serves as an overall framework for future development that coordinates with both the municipal and provincial governments.

Frances Baard created a formal GIS organization in 2009 (called the Corporate GIS unit) to facilitate water and electricity service delivery and assist with rezoning, infrastructure development, and maintenance. While the district already had a legacy system in place, it determined that an enterprise solution was the only practical way to connect and collaborate directly with the local municipalities it must support.

After a thorough internal review with stakeholders from the Corporate GIS unit and district leadership, Frances Baard contacted Esri South Africa (Pty) Ltd. to implement an enterprise solution based on ArcGIS.

Developing an Accurate Land Base

The Corporate GIS unit's first major task was to perform a comprehensive audit of existing land records for all the local municipalities it supports. Using data, such as cadastral and lease data provided by the surveyor general, the Corporate GIS unit created a new cadastral dataset that served as a starting point in the audit process. The unit also obtained land records information from the Deeds Office that could then be used to verify and update ownership information and property boundaries.

After converting all the data to a common coordinate system and projection, staff began auditing the data by selecting five random parcels from each General Plan (an area of establishment that can number more than 200 individual parcels). Technicians compared the selected parcels to the diagrams and boundary documents from the surveyor general. They fixed any spatial errors by re-creating the parcels in ArcGIS based on the coordinates provided in source documents from the surveyor general. When coordinate information was insufficient due to age or imprecision, the technicians used aerial photography to create boundaries that reflected information in the diagrams.

Once the spatial audit was completed, the cadastral dataset was then linked to the Deeds Office database to compare and update ownership information. Any properties that matched between the new cadastral dataset and the Deeds Office records were moved to a registered cadastral layer. When properties did not match, staff researched deed information from the surveyor general and linked the property to the last known owner before adding it to the registered cadastral layer. Any properties that did not match and could not be resolved were registered back to their parent properties and moved into the registered cadastral layer.

Updating Community Facility and Water Infrastructure Data

Equipped with the approved cadastral layer, the Corporate GIS unit needed to survey and record information related to community facilities and water infrastructure to create a complete GIS database for the district. To obtain the most accurate and current information possible, the district purchased Trimble Juno GPS units for field data collection. Staff from the local municipalities and selected students were then trained on the units and directed to capture data about key facilities, such as schools and clinics throughout the district. This project had the joint effect of developing more accurate data for the district and promoting technical education for both the students and local staff.

The rural setting where staff and selected students were trained to use Trimble GPS units.

Similar to the community facilities effort, the district once again employed field data collection to confirm and, in many cases, update existing water utility information in ArcGIS. Data from the field was compared to existing GIS data to confirm as-built drawings and determine the actual location of various infrastructure. To date, the district has only completed verification of bulk water infrastructure but plans to address reticulation infrastructure in the future.

Implementing ArcGIS has allowed the Corporate GIS unit to produce detailed landownership maps for the various municipalities it supports.

Improving Revenues and Planning

The creation and verification of Frances Baard's GIS database have improved service delivery for the district, as it now has a better understanding of where customers are located and how many are being served in each area. This has led to more accurate utility billing, which in turn has created a better revenue stream for the district. The updated infrastructure data has also helped the district better maintain its facilities and plan for the future.

Using ArcGIS, the Corporate GIS unit has made its data available to all municipalities through a web portal. Local authorities at the municipalities can use this information for decision making, planning, and asset verification. As a result of the shared data and field data collection projects, the local municipalities have also begun identifying staff that can serve as local GIS coordinators to maintain data and support future projects.

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Sustainability in Africa

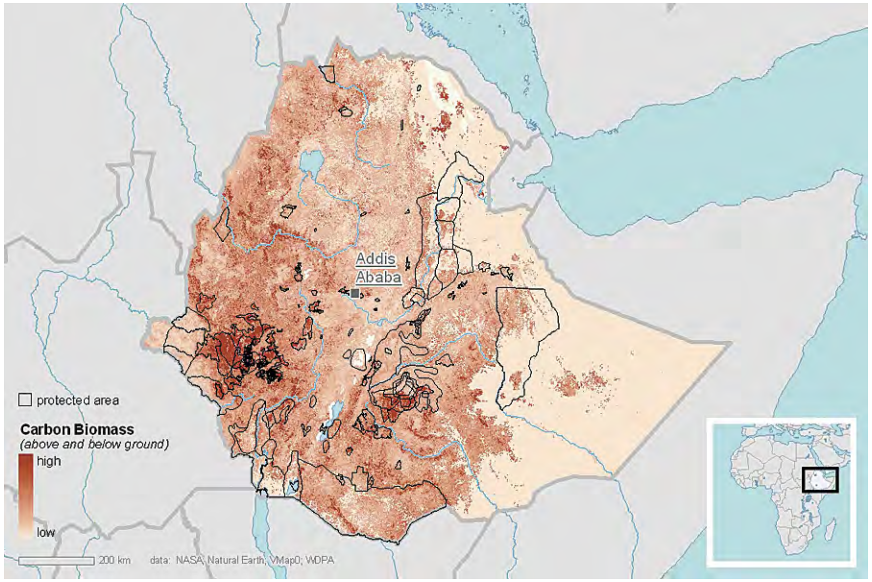
By Peter A. Seligmann and Sandy J. Andelman, Conservation International

"We need to take stock and attach value to our natural resources and ecosystems, such that we may include their value in planning and decision-making processes, as well as in our national accounts and balance sheets."

Although His Excellency President Ian Khama of Botswana was speaking about Africa in his opening remarks to the first Summit for Sustainability in Africa, his words apply equally to the rest of the globe.

The goal of the summit, hosted in Gaborone last May by the government of Botswana and Conservation International, was to demonstrate how African nations and their investment partners understand, manage, and value natural capital to support and improve human well-being. The aim was to take a practical, results-focused approach, with African nations leading and encouraging investment partners to provide support in a coordinated and coherent fashion.

The term *natural capital* refers to earth's natural assets (soil, air, water, plants, and animals) and the ecosystem services resulting from them (e.g., food production, climate regulation, pollination, flood protection) that sustain human life.



This map was part of a series created for the first Summit for Sustainability in Africa, held in Gaborone in May 2012 to demonstrate the natural capital of participating countries. In this example, the ecosystem service of climate regulation through carbon storage is shown, along with the country's protected area network.

The visionary heads of state and ministers of 10 African nations—Botswana, Gabon, Ghana, Kenya, Liberia, Mozambique, Namibia, Rwanda, South Africa, and Tanzania—unanimously voiced their support for the value of natural capital in national accounting. These nations reached two key conclusions. First, there was unanimous consensus that the historical pattern of resource exploitation has failed to promote sustained growth, environmental integrity, and improved social capital and has, even worse, been counterproductive. Second, they agreed that the value of natural capital—the wealth of benefits provided to people by biodiversity and ecosystems, like watersheds, forests, coral reefs, and grasslands—must be fully accounted for and integrated into national and corporate planning, as well as reporting practices, policies, and programs.

The message resulting from the summit—the Gaborone Declaration—reaffirmed a commitment to sustainability already shared by these visionary leaders. The declaration signaled a new era of leadership, rooted in Africa, that understands, values, and manages the natural capital that sustains all of us: a platform on which we can begin to build a sustainable future.

Summit participants included Sam Dryden, director of agricultural development at the Bill & Melinda Gates Foundation; Laurene Powell Jobs, chair and founder of Emerson Collective; Rachel Kyte, vice president of sustainable development at the World Bank; Rob Walton, the chairman of Walmart; and numerous other private- and public-sector partners from within and outside Africa. These participants also issued a communiqué to draw attention to what they described as "the limitations of GDP [gross domestic product] as a measure of well-being and sustainable growth that values environmental and social aspects of progress."

In closing the summit, President Khama emphasized the importance of following through on these commitments. "This meeting will not be of any value to our peoples if we fail to achieve the objectives that formed the core of this summit, that is, integrating the value of natural capital into national and corporate accounting and planning," he said. "We must continue building social capital and reducing poverty by transitioning agriculture and extractive industries to practices that promote sustainable employment and the protection of natural capital while building the knowledge, capacity, and policy networks needed to promote leadership and increase momentum for change."

This is true leadership and an example we should celebrate and follow.

The Gaborone Declaration marked an important step in paving the way toward mutually beneficial partnerships between governments and businesses. A month later, at Rio+20—the United Nations Conference on Sustainable Development—these 10 African nations united under the Gaborone Declaration and emerged as global leaders. They urged others to join them in taking the first steps to correct what has been, up until now, a misguided development trajectory. They were followed by 49 other nations, developed and developing alike, along with nearly 100 public, private, and civil society partners, including ArcelorMittal, the Coca-Cola Company, the Bill & Melinda Gates Foundation, the German Development Institute, the MacArthur Foundation, the United Nations Environment Programme, the

United Nations Permanent Forum on Indigenous Issues, Walmart, Woolworths, the World Bank, and World Vision.

Measuring Sustainability: Getting the Metrics and Measurements Right

The recent Stiglitz-Sen-Fitoussi Commission on the Measurement of Economic Performance and Social Progress (2009) put it very clearly:

> *What we measure affects what we do; and if our measurements are flawed, decisions may be distorted. . . . Those attempting to guide the economy and our societies are like pilots trying to steer a course without a reliable compass. The decisions they make depend on what we measure, how good our measurements are and how well our measures are understood. We are almost blind when the metrics on which action is based are ill-designed or when they are not well understood. . . . We need better metrics.*

Ecosystem goods and services from natural capital provide an enormous contribution to the global economy, but natural capital has not been factored into conventional indicators of economic progress and human well-being like GDP or the human development index (HDI). Neither GDP per capita nor the HDI reflect the state of the natural environment. Both indicators focus only on the short term, giving no indication of whether current well-being can be sustained for future generations.

Many economists and politicians have become convinced that the failure of societies to account for the value of natural capital—as well as the use of indicators of well-being that don't reflect the state of natural capital—have contributed to degradation of the natural environment. We are using a flawed measurement approach to guide policy and decision making, and one key step toward achieving healthy, sustainable economies is to begin accounting for our use of natural capital. We must recognize and report the true cost of economic growth and our ability to sustain human well-being, both today and in the future. By incorporating the value of natural capital and ecosystem services, such as water provision, climate regulation, soil fertilization, or plant pollination, into our balance sheets, governments and businesses will be able to see a more holistic and accurate picture of natural and national wealth.

Sustainability and Food Security: Grow Africa and the G8 New Alliance for Food Security and Nutrition

Ann's story that follows is representative of hundreds of millions of farmers across sub-Saharan Africa. The continent's smallholder agricultural systems have inadvertently degraded vital ecosystem services like flood protection, water supply, and soil nutrient cycling:

Ann is 75 years old, a feisty grandmother in Wasare, Kenya, near Lake Victoria. She remembers five decades ago as a fish trader, when the water was clear, fish were abundant, the hilltops were green and lush, and harvests were plentiful. Now, she barely ekes out a living on her family farm. Like all her neighbors', Ann's field is planted with corn, but the soil underneath the rows of corn is gravely wounded and pale, drained of vital minerals. Gulleys scar the landscape, evidence of sustained hemorrhaging of fertile soils.

The harvesting of amaranth greens.
(Photo courtesy of Conservation International. Copyright © Benjamin Drummond.)

According to Jon Foley of the University of Minnesota, feeding the growing world population in the next 40 years will require producing as much food as we have produced in the last 8,000 years. This equates to a 70–100 percent increase in food production through agricultural intensification and expansion, mainly in developing countries. In this context, Africa is central to solving the world's food security and sustainability challenges. Africa contains 12 percent of the globe's land that is suitable for agriculture, but only 33 percent of this land currently is cultivated. Africa also offers significant opportunities to increase production on existing agricultural lands by filling yield gaps (i.e., the difference between current crop yields in a given location and the potential yield for the same location) using improved agricultural management and new technologies.

Two other processes that focus on food security and involve many of the same governments and private-sector players are the World Economic Forum's Grow Africa Initiative and the G8 New Alliance for Food Security and Nutrition. These initiatives have been moving forward, largely independently of and parallel to the Summit for Sustainability in Africa and Rio+20, yet they underscore the importance and timeliness of the Gaborone Declaration.

Building on public-private partnership models piloted by the World Economic Forum's New Vision for Agriculture Initiative, Grow Africa is a public-private partnership platform. It aims to accelerate investments and transform African agriculture in accordance with national agricultural priorities and in support of the Comprehensive Africa Agriculture Development Programme, a program of the New Partnership for Africa's Development established by the African Union in 2003. At the Grow Africa Investment Forum last May, held at the glamorous African Union Conference Centre in Addis Ababa, seven African governments presented opportunities for multinational, private-sector investment.

Also in May, at Camp David (the US president's retreat in Frederick County, Maryland), the G8 countries announced the New Alliance for Food Security and Nutrition. The New Alliance, also a public-private partnership, is being promoted as a mechanism to raise 50 million people in Africa out of poverty over the next 10 years. The G8 committed $1 billion, together with $3 billion in pledges from 45 agribusiness companies, and is initially targeting Ethiopia, Ghana, and Tanzania. While applauding the focus on lifting 50 million people out of poverty, several African civil society groups and international organizations, such as the agency Oxfam, have criticized the alliance's top-down approach and its failure to bring smallholder farmers—particularly women—to the table. They have also voiced concern about its lack of attention to environmental sustainability.

We are clearly gaining traction and attention on these critical challenges, but we need to integrate our efforts to strengthen our collective impact.

Looking Ahead to Increased Sustainability

As stated by Kenyan Alex Awiti, director of the East African Institute at Aga Khan University in Nairobi, "A fundamental question underlies Africa's socioeconomic and environmental sustainability: How can smallholder farmers increase land productivity, profitability, and human well-being outcomes without causing irreparable damage to the natural world on which they depend?"

Africa's smallholder production systems, like global agricultural production systems, depend on essential natural capital—the ecosystem services produced by ecosystems at many spatial scales, such as rainfall and water captured by forests or from underground aquifers or vegetation from grasslands and savannas to feed cattle, goats, and sheep. As a result, solutions to the challenges faced by smallholder farmers require a landscape-level approach.

However, much of the existing knowledge of ecosystems and agricultural systems in Africa is local, fragmented, often inaccessible, and seldom mapped at the scales relevant for decision making. As a result, policy makers, farmers, and investors often make important land-use and land management decisions based on partial and incomplete understanding of landscape-level interactions and feedback.

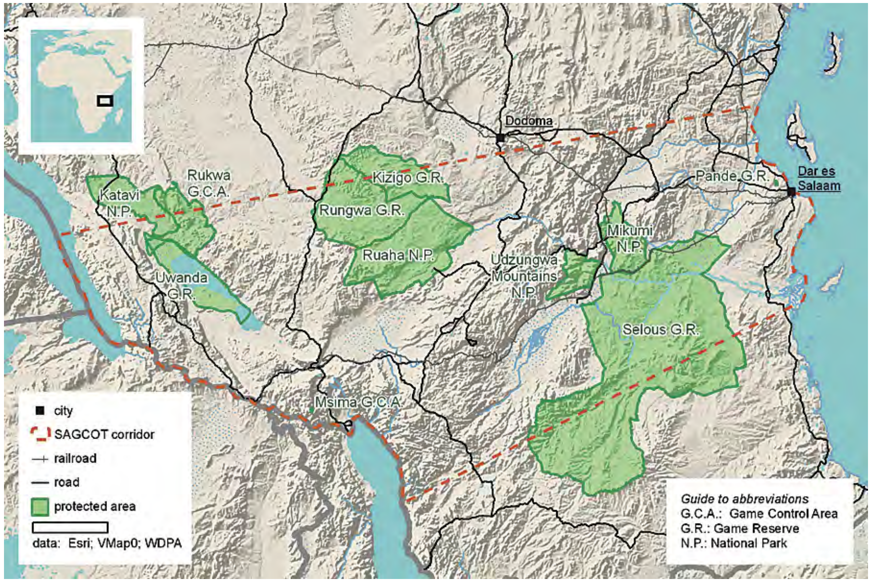
Without concerted investments in a framework with the right metrics, indicators, and data to track changes in ecosystem services and human well-being, gains in food production are unlikely to be sustainable in the long run. At worst, they may unintentionally degrade the environment.

Conservation International and partners have argued, therefore, for a new, holistic, evidence-based approach to supporting African agriculture, one that improves decisions on sustainable land use and land management and provides a holistic understanding of ecosystem health and human well-being.

Africa needs an integrated diagnostic and monitoring framework to generate data and information at appropriate scales to support decision making at household, national policy, and international and global investment levels: an instruction manual, if you will, to ensure that communities, investors, growers, and decision makers are operating in sync. Such a framework requires a strategically selected set of indicators that integrate information about land productivity, soil and plant health, biodiversity, water availability, and human well-being in a scientifically credible way. At the same time, the set of indicators must be small enough that decision makers aren't overwhelmed with too much information.

Farmers like Ann, African governments, and investors like the G8 and multinational corporations need a system of metrics and indicators that provide information at the right scales. These indicators are the missing piece that will help minimize environmental impacts of food production, as well as ensure that the well-being of Ann and millions of farmers like her across sub-Saharan Africa can be improved in a sustainable manner.

Over the last two years, with funding from the Bill & Melinda Gates Foundation, Conservation International has worked together with a broad set of science and policy partners to identify the right set of metrics for measuring natural capital. These metrics are intended to map the flow of ecosystem goods and services to people and to quantify the contributions of



Map showing the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), where the government is attempting to transform agricultural development, increase food production, and reduce poverty through a targeted program of public-private partnerships. The corridor is critically important for maintaining natural capital and contains important protected areas that also provide revenue from ecotourism.

these services to human well-being. We tested this framework in southern Tanzania, including the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), where the country's government is attempting to transform agricultural development, increase food production, and reduce poverty through a targeted program of public-private partnerships. The corridor is critically important for maintaining natural capital and contains important protected areas that also provide revenue from ecotourism. As with Grow Africa, some questions and concerns are being raised with respect to SAGCOT: whether it is commercially viable, whether large commercial farms will dominate the landscape at the expense of the region's poorest farmers, whether investments will be transparent, whether fears of land grabbing will be addressed, and whether there will be transparent processes for investments and auditing. Without access to integrated information on the socio-agroecosystems within the corridor—information that can gauge the success of the agricultural investments and the environmental and socioeconomic outcomes—there is significant risk that SAGCOT will fall short of its transformational goals.

Vital Signs Africa

Having identified the metrics and demonstrated the feasibility of making the necessary measurements at the right scales, we're ready to think bigger, act bigger, and dramatically scale up. Recently, Conservation International, in collaboration with Columbia University, the Council for Scientific and Industrial Research in South Africa, and the Earth Institute, launched Vital Signs Africa, an integrated monitoring system for agriculture, ecosystem services, and human well-being. The first phase of Vital Signs, funded by the Bill & Melinda Gates Foundation, focuses on regions in five countries in sub-Saharan Africa, including Ethiopia, Ghana, and Tanzania. These regions were selected because they are where agricultural transformation is targeted to meet the needs of Africa's growing population. Measurements will be collected through a combination of ground-based data collection, household surveys, and high-resolution and moderate-resolution remote sensing.

Currently, no African countries have environmental monitoring systems, and Vital Signs aims to fill that gap. The system emphasizes capacity building, working through subgrants to local scientists who will collect information and partnerships with existing data collection efforts, such as the Tanzania National Bureau of Statistics. It focuses on building local capacity for analysis and synthesis of spatial information, as well as on the capacity of African policy makers and institutions to understand and use this kind of information.

Data collection will happen at multiple scales to create the most accurate possible picture: a household scale, using surveys on health, nutritional status, and household income and assets; a plot scale to assess agricultural production and determine what seeds go into the land, where they come from, what kind of fertilizer is used, what yield of crops they deliver, and what happens after the harvest; a landscape scale (100 km^2) measuring water availability for household and agricultural use, ecosystem biodiversity, soil health, carbon stocks, etc.; and a regional scale (~200,000 km^2) that will tie everything together into a big picture to enable decision makers to interact with the information at the scales on which agricultural development decisions are made. High-resolution (e.g., QuickBird, WorldView-2) and moderate-resolution (e.g., Landsat, SPOT) remote sensing will provide wall-to-wall coverage.

Vital Signs aims to fill the crucial information gap, providing a set of metrics to quantify the value of natural capital for agriculture and for human well-being; using the right measurements at the right scales; and offering a set of indicators and tools to provide policy makers, farmers, and investors with the holistic understanding they need for better decision making.

These are long-term endeavors that will take time to realize but offer a smarter way forward as we work to build healthy, sustainable economies that support people and our planet.

The Geospatial World of Conservation International

Armed with an Esri nonprofit organization site license, for many years Conservation International (CI) has partnered with Esri and Esri Partners and users to provide data and geospatial analysis that has made a world of difference. To name merely a few, CI uses ArcGIS for the following:

- As the core analytical engine for its automated near real-time monitoring systems, serving more than 1,200 subscribers in Madagascar, Indonesia, Bolivia, and Peru
- To analyze trade-offs between multiple ecosystem services and stakeholders linked to land use and water quality management in the Great Barrier Reef, Australia
- To define site- and landscape-level conservation priorities in collaboration with regional partners to guide conservation action and funding in the Mediterranean Basin, Caribbean, Eastern Afromontane, Indo-Burma, and East Melanesian Islands biodiversity hot spots
- To analyze land use and natural resources to inform various development scenarios in the Cardamom Mountains of Cambodia to guide government policy makers

About the Authors

Peter A. Seligmann is chairman and chief executive officer of Conservation International and has been a leader in creating conservation solutions for the past 36 years. Since he founded the organization in 1987, Conservation International has earned a reputation as an organization on the cutting edge, creating innovative and lasting solutions to the threats facing humanity, biodiversity, and the natural systems that sustain us all. Dr. Sandy J. Andelman is the executive director of the Vital Signs Monitoring System and is a vice president at Conservation International. Vital Signs fills a critical unmet need for integrative, diagnostic data on agriculture, natural capital, and human well-being. Andelman has pioneered the creation of global monitoring and forecasting systems for climate change and ecological change.

For more information, visit conservation.org or vitalsigns.org.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

Can GIS Help Fight the Spread of Malaria?

Zambia Tries Out New Tactic on an Old Opponent

By Emmanuel Chanda, Victor Munyongwe Mukonka, David Mthembu, Mulakwa Kamuliwo, Sarel Coetzer, and Cecilia Jill Shinondo

In Zambia, which is situated in southern Africa, malaria remains a major cause of illness and mortality. Its transmission is driven by a complex interaction between the vector (i.e., the mosquito that transmits the disease), host, parasite, and the environment and is governed by different ecological and social determinants. The survival and adaptation of malaria vectors are affected by climate variability, that is, variability in rainfall, temperature, and relative humidity. As a result, even minute spatial variations and temporal inconsistencies in the mosquito population can significantly increase the risk of malaria.

Zambia has a population of approximately 12 million people, 45 percent of whom are under 15 years of age. Malaria is endemic countrywide, and its transmission occurs throughout the year, with a peak in the rainy season. The disease is the leading cause of morbidity and mortality, accounting for 40 percent of outpatients and 45 percent of hospital admissions, with 47 percent and 50 percent of disease burden, respectively, among pregnant women and children under five years of age. Current trends in the country indicate that malaria is responsible for at least 3 million clinical cases and about 6,000 recorded deaths annually, including up to 40 percent of the under-five deaths and 20 percent of maternal mortality.

Since malaria is not evenly distributed, much effort needs to be expended toward defining the local spatial distribution of the disease before the deployment of vector control intervention measures (i.e., indoor spraying and the distribution of insecticide-treated nets [ITN]) in accordance with World Health Organization (WHO) protocols. Furthermore, insecticide resistance is a growing problem that must be factored into decisions.

However, in resource-constrained environments, monitoring and evaluation are often neither thorough nor regular and tend to lack the important spatial and temporal distribution patterns. Therefore, if transmission-determining parameters are to be harnessed effectively for decision making and objective planning, implementing, monitoring, and evaluating viable options for malaria vector control, those parameters must be well organized, analyzed, and managed in the context of a GIS-based decision support system (DSS).

The usefulness of an ArcGIS software-based DSS for planning and managing control programs is, of course, dependent on the availability of accurate and raw data on malaria transmission-related parameters. The monitoring and evaluation of malaria interventions and an understanding of their true impact on disease burden are essential for measuring the performance of a control program.

Receiving a shipment of insecticide-treated nets is cause for celebration.

The ability of the DSS to deal with large datasets and incorporate maps, satellite images, and aerial photos increases the feasibility of studying transmission determinants of malaria and has resulted in the prompt availability of data to support surveillance and policy formulation. The epidemiological mapping of high-risk areas of malaria transmission and the insecticide resistance profiles of major vectors has facilitated the recognition of those populations and geographic areas where it is possible to identify the main determinants of malaria morbidity and mortality. The revealed trends and interrelationships have allowed the identification of high-risk areas and facilitated decision making and the rational utilization of limited resources for targeted, high-impact interventions in a cost-effective manner.

Herein is provided a review of data related to the operational use of a GIS-based DSS for optimal deployment, monitoring, and evaluation of entomological interventions for malaria control in Zambia.

Intervention

Indoor residual spraying (IRS) of a variety of insecticides in urban areas is implemented through annual campaigns, with 85 percent coverage of eligible households at the beginning of the peak malaria transmission period. ITNs are deployed in rural areas through antenatal and child clinics, equity programs, community mass distribution, and the commercial sector and strive toward attaining 100 percent coverage in eligible areas.

Indoor residual spraying is implemented through annual campaigns with 85 percent coverage at the peak malaria transmission period.

Stratification

The protozoan parasite *Plasmodium falciparum* accounts for 98 percent of all malaria infections in the country, causing the severest form of the disease. The national malaria indicator survey for 2010 in children under five years of age shows great spatial variance in the prevalence of infection.

This has resulted in the stratification of the country into three epidemiological categories:

- Type 1 areas with very low transmission and parasite prevalence of less than 1 percent
- Type 2 areas with low transmission and prevalence of less than 10 percent
- Type 3 areas with persistent high transmission and prevalence exceeding 20 percent at peak transmission season

Malaria stratification aids in the development of community-based malaria control programs by accumulating past experiences with and solutions to different factors associated with malaria outbreaks. Stratification can also point to the existing inequalities in resources, allowing for a more equal and homogeneous distribution of available resources.

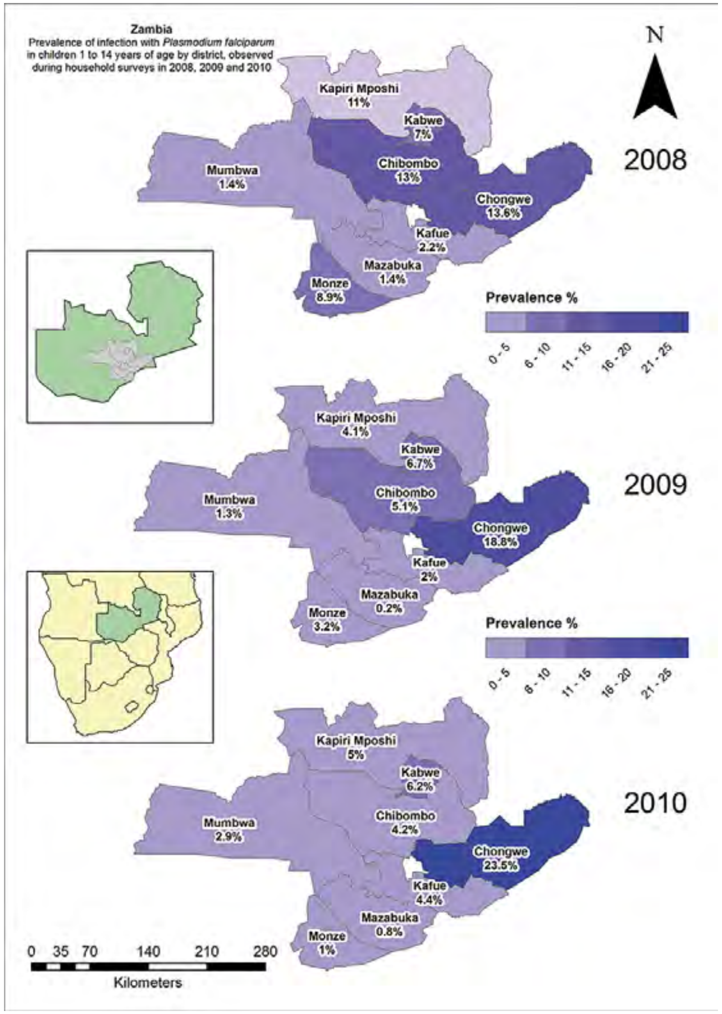
GIS-Based Sentinel Sites

In this regard, to allow for adaptation of intervention policy, procedures, and methods to better the outcomes, vector control interventions on parasite prevalence in children between 1 and 14 years of age have been monitored through annual malaria surveys for three consecutive years at 19 GIS-based sentinel sites, distributed among nine districts within a 350-kilometer radius of the capital, Lusaka. These sites were established for the continual monitoring and collation of key malaria data, such as parasitemia risk, insecticide resistance profiles in vectors, and impact of interventions on malaria prevalence. The use of the GIS-based DSS has allowed the identification of areas that require specific targeted intervention for impact, either through the use of ITNs or IRS or a combination of both.

Spatial Monitoring of Interventions

The spatial and temporal impact of indoor spraying and insecticide-treated nets on human parasite prevalence and insecticide resistance status in major malaria vectors was monitored. At each sentinel site, household surveys were carried out annually from 2008 to 2010 to measure *P. falciparum* prevalence in children aged 1 to 14. In Zambia, three nationally representative malaria indicator surveys (MISs) were also conducted in children under five years of age in 2006, 2008, and 2010. The MISs have been used to estimate an empirical high-resolution parasitological risk map in the country and assess the relationship between malaria interventions and parasitemia risk. The spatial impact of interventions and the overall prevalence of infection are as follows:

- Children who lived in a house that had not been sprayed in the past year and did not sleep under a net the night before the survey had a prevalence of infection of 6.8 percent.
- Children who slept under a net but lived in a house that had not been sprayed during the past year had a prevalence of infection of 5.2 percent.



The prevalence of infection with *P. falciparum* in children 1 to 14 years old as observed during the annual parasitemia surveys from 2008 to 2010 by district.

- Children who lived in a house that had been sprayed during the past year but did not sleep under a net had a significantly lower prevalence of infection of 3.2 percent.
- Children who slept under a net in a dwelling that had been sprayed had the lowest risk of infection, with a prevalence of infection of 2.6 percent. Thus, an incremental effect was observed for the combined use of IRS and ITNs.

The mosquito—a major malarial vector.

Spatial Distribution of Insecticide Resistance Profiles

The ArcGIS software-based DSS has been used to collate data on insecticide resistance in Africa. By standard WHO protocol, the spatio-temporal insecticide resistance profiles of major malaria vectors—*Anopheles gambiae s.s.*, *An. arabiensis*, and *An. funestus*—were determined at sentinel sites and extended to other regions of the country. More data on the spatial distribution of resistance to five different insecticides has been collected by different partners and collated by the National Malaria Control Programme. Data on suspected and overt resistance to insecticides is being harnessed for vector control. The marked insecticide resistance problem in indoor spraying sites confirms other findings of resistances developing in the wake of extensive vector control. This allows the malaria control program manager to better utilize the limited resources on insecticides to which the malaria vectors are still susceptible. Detection of high resistance levels has facilitated the planning of rational insecticide resistance management strategies and the introduction of alternative non-insecticide-based vector control interventions.

In Zambia, monitoring the impact of vector control through a GIS-based decision support system has revealed a change in the prevalence of infection and vector susceptibility to insecticides and has enabled measurement of spatial heterogeneity of trend or impact. The revealed trends and interrelationships have allowed the identification of areas with reduced parasitemia and increased insecticide resistance, thus demonstrating the impact of resistance on vector control. The GIS-based DSS provides the opportunity for rational policy formulation and the cost-effective utilization of limited resources for enhanced malaria vector control.

Conclusion

Routine surveillance data has proved inadequate for monitoring control programs and is presently being supplemented by parasite prevalence surveys; vector-borne diseases demonstrate decided geographic heterogeneities and therefore require special tools for analysis. With its inherent ability to manage spatial data, GIS provides an exceptional tool for continuous surveillance and a framework for harmonizing surveillance data and parasitemia survey data. At a regional level, the ability of GIS to display data in an intuitively understandable manner has been harnessed to establish a continental database in Africa of the spatial distribution of malaria. The GIS-based DSS has not only streamlined the evidence-based implementation of intervention measures but has also improved the tracking of entomological indicators: species characterization and insecticide resistance status, including parasite prevalence and impact assessment of ITNs and IRS. For resource-constrained malaria-endemic sub-Saharan African countries like Zambia, the need for a GIS-based malaria information system cannot be overemphasized. Until recently, decisions in the malaria control programs were taken on an ad hoc basis driven by limited empirical evidence, undoubtedly resulting in the misdirection of the limited available resources.

About the Authors

Emmanuel Chanda of the National Malaria Control Centre, Ministry of Health, Lusaka, Zambia, coordinated and participated in data collection, analyzed the data, and drafted this article. Victor Munyongwe Mukonka, also of the Ministry of Health, and Mulakwa Kamuliwo of the National Malaria Control Centre, Ministry of Health, were both responsible for management of the project and contributed to the drafting and critical evaluation of the paper article. David Mthembu and Sarel Coetzer of the Malaria Research Programme, Medical Research Council, Durban, South Africa, participated in field survey data collection and mapped the sites. Cecilia Jill Shinondo of the School of Medicine, University of Zambia, contributed to the drafting, review, and critical evaluation of the article.

See also "World Health Decision Makers Should Consider GIS."

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Understanding Deforestation in Eastern Democratic Republic of Congo

By Fabiano Godoy, Conservation International, and Wegener Vitekere
and Luc Lango, Tayna Center for Conservation Biology

Created in 1998, the Tayna and Kisimba-Ikobo Nature Reserves are located in the province of North Kivu in eastern Democratic Republic of Congo (DRC). Both reserves were created and are administered by the local customary powers given to the Bamate, Batangi, Kisimba, and Ikobo traditional communities, with the intention to preserve the biologic heritage and foster social development. In 2006, after dialog with the Ministry of Environment and the Congolese Wildlife Authority, the reserves were recognized, opening a new model of community-managed conservation areas.

Together, the reserves cover an area situated between the lowlands of the Congo Basin and the highlands of the Albertine Rift. This area is noted for its globally significant biodiversity, containing more than 45 threatened species of fauna and flora recorded in the Red List by the International Union for Conservation of Nature. In addition, there are high numbers of endemic and restricted-range species, like the eastern lowland Grauer's gorilla (*Gorilla beringei beringei*), the okapi (*Okapia johnstoni*), and the African elephant (*Loxodonta africana cyclotis*). The region contains the largest remaining block of intact forest in the Congo Basin, which is at the headwaters of the Congo River

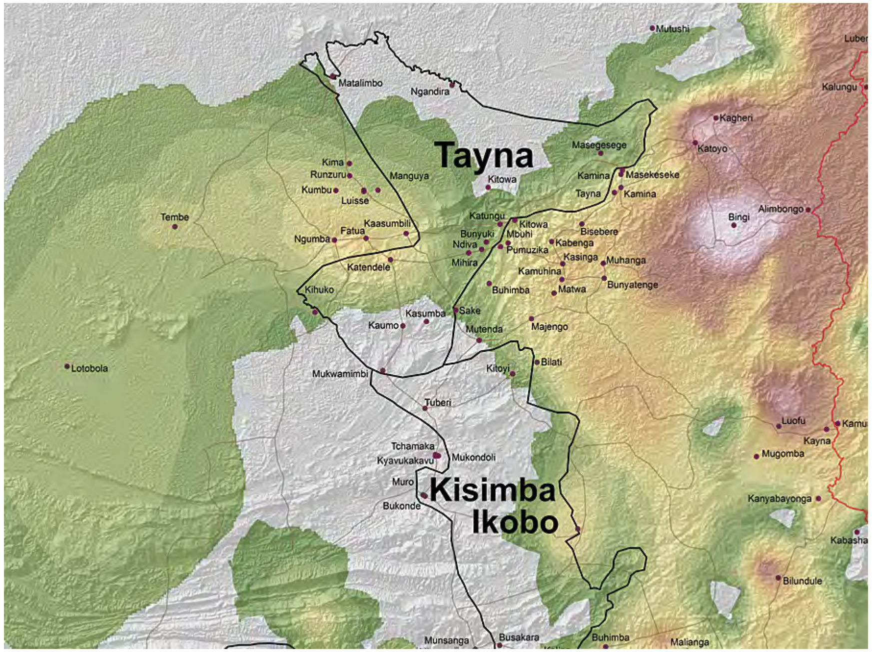
Field researchers collecting biodiversity data in the nature reserves.
(Photo © CI/Photo by John Martin)

and plays a crucial role regulating local and global climate and soil protection.

Despite great effort from local communities to protect the reserves, the surrounding region is under a great and imminent threat. Forest fragmentation is one of the greatest threats to the health of the environment, isolating species communities and degrading important environmental services. Local villages also rely on the natural resources, primarily firewood, fish, clean water, and plants for food and medicine.

Habitat destruction, mainly caused by forest conversion to agriculture and unsustainable logging, is advancing toward the reserves and jeopardizing the integrity of ecosystem services. According to the atlas produced by the Observatoire Satellital des Forêts d'Afrique Centrale, between 2005 and 2010, DRC lost 1,976,000 hectares of forest, the equivalent of about 1,000 soccer fields, per day. Local human population has grown in the same period, increasing the timber demand for housing materials and land for crops and pasture.

In response to these issues, the local communities have partnered with Conservation International to implement a project to improve human well-being while conserving the natural resources and the provision of ecosystem services. To better design strategies to mitigate the causes of forest loss, local leaders and experts are engaged in a consultation process to identify the main agents and drivers of deforestation in the

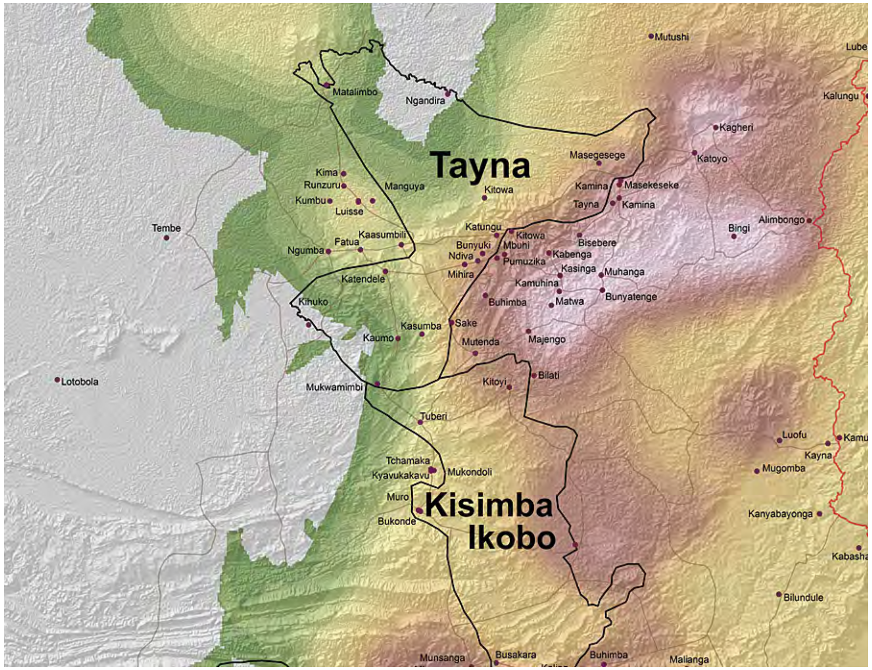


The distribution of the major drivers of deforestation in the recent past (approximately 2000–2010) was mapped based on local knowledge and validated with the actual forest cover and change imagery.

region. They are also working to determine the correlation with the underlying causes and map the distribution of threats in the past (approximately 2000 to 2010) and in the future (approximately 2010 to 2020). Six major threats to the forest were identified: conversion to agriculture, conversion to pastureland, infrastructure/new settlements, mining, firewood collection, and illegal logging.

The data was compiled and analyzed by Conservation International, an organization with an Esri nonprofit organization site license agreement. Conservation International used ArcGIS to digitize the maps depicting the threat distribution, assign the severity in each polygon, and generate the cumulative threat map; such processing was done for past and future threat locations. Due to the subject nature of defining physical boundaries of threats, the limits of the cumulative threats were not the best representation of the results. The polygon-vector files were then converted to rasters and the boundaries smoothed. To generate the soft surface, random points were allocated over the study area, and the kriging interpolation tool was applied. Local knowledge was validated by comparing the past threat distribution map with the actual deforestation map generated by satellite imagery classification. The future threats maps will be used to validate the output from a deforestation model. "This approach was an excellent example of combining local knowledge and science, and the final product could be a very powerful management tool for the communities," says Susan Stone, senior director for social policy and practice at Conservation International.

Information about biodiversity is currently being added to the GIS—for example, observations of gorilla and chimpanzee groups and nests that have been collected by the communities since 2002. This data will be used to measure the impact of mitigation activities on biodiversity. In addition, maps depicting deforested



The distribution of the major drivers of deforestation in the future (approximately 2010–2020) was estimated based on local knowledge.

areas, critical areas for conservation, and potential areas for sustainable use are being used to raise conservation awareness in the community and among the students of the Tayna Center for Conservation Biology (TCCB). Wegener Vitekere, a lecturer at TCCB, highlights that "The GIS should not be considered only as a tool but also as a service that should be present in the management of a protected area and be beneficial to the people living in the protected areas."

Another output from the public consultation was a conceptual model that provides a comprehensive overview of the causes and illustrates the relationship between contributing factors and deforestation. Together with the threat maps, the conceptual model is being used to identify key areas to implement mitigation strategies, as well as to define expected impacts and establish a monitoring system.

About the Authors

Fabiano Godoy is a cartographic engineer with an MSc in sustainable development and conservation biology. He has been working at Conservation International since 2006 developing deforestation models. Wegener Vitekere has been a junior lecturer and researcher at the Tayna Center for Conservation Biology since 2010. Luc Lango is from the Batangi community and since 2008 has been working as research manager at Tayna Center for Conservation Biology. He holds a BSc in ecology and animal resources management.

(This article originally appeared in the Summer 2012 issue of *ArcNews*.)

From Urban California to Rural Kenya

Applying the UPlan Model

By Karen Beardsley, Managing Director, Information Center for the Environment, University of California, Davis

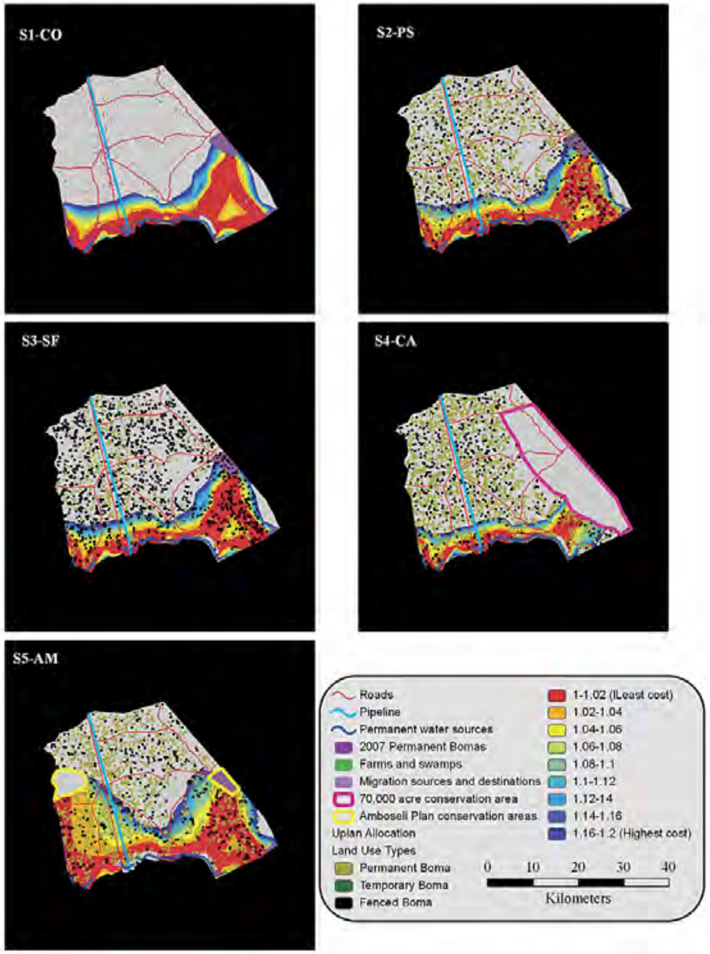
After centuries of a pastoral way of life, with livestock providing the basis for sustenance, many Maasai pastoralists in southern Kenya have been transitioning from communal land tenure to individual parcel ownership. The introduction of private landholdings frequently leads to a more sedentary, crop-based livelihood, and the land is often demarcated with fences. Effects of land subdivision go beyond the direct changes to people's landownership to include landscape-scale habitat fragmentation, reduced resistance to drought, and a decrease in wildlife populations. Some of the group ranches in southern Kenya have completely converted from communal lands to individual landownership, while others still have a choice in setting their land-use policies but are struggling with decisions about the future of landownership, subdivided or not.

A Maasai herdsman.

There have been few if any systematic methods for estimating longer-term impacts of differing land-use scenarios on wildlife and other environmental resources in Africa. At the University of California, Davis, Information Center for the Environment (ICE), researchers endeavored to model and visualize some of the land-use issues facing the Maasai in Kenya with UPlan, an urban growth GIS modeling tool (see "How UPlan Works in California"). UPlan was developed to simulate growing urban areas of California and is widely used for long-range planning in rapidly growing cities. This would, at first glance, seem to have nothing in common with sparsely populated pastoral lands in East Africa. But the author, one of the ICE researchers, had been a Peace Corps volunteer in Kenya 20 years earlier and has connections (through the Society for Conservation GIS) with the African Conservation Centre (ACC) based in Nairobi, Kenya.

In summer 2007, the author spent three weeks in Kenya working with scientists at ACC visiting areas outside park boundaries, where ACC focuses most of its conservation efforts, and learning more about the issues facing the historically pastoralist communities. Potential land-use conflicts included a complex and interacting mix of livestock grazing lands, wildlife corridors, agricultural lands, and human settlements. Combining her knowledge of UPlan and ArcGIS with her interest and experience living in Kenya, she and ACC developed a plan for this collaborative work, adapting UPlan for use in a rural setting far away from its traditional applications in the cities of California.

In general, people prefer pictures or maps over reams of numbers to help them understand the world now and in the future. Geographic tools, such as ArcGIS, provide a visual framework within which to view the future or, better yet, a variety of possible futures. When dealing with the past or the present, scientists typically seek complete, unbiased data at the maximum resolution practical. This is not so when looking into an unknowable future. The UPlan urban growth model is an appealingly simple and easy-to-understand tool, built in ArcGIS, that has been far more instrumental in helping planners see what California's future might look like than similar, but more complex, models. The application of UPlan to rural Kenya explores some of the ways that ArcGIS can be



UPlan's output from five different Mbirikani scenarios, based on past trends, various degrees of fencing, and different management plans involving Mbirikani, will assist researchers and ultimately local ranch members with land subdivision decisions.

designed to peer into the future at a low resolution and with multiple potential outcomes for a rural region experiencing rapid land-use change.

ICE researchers gathered existing data from many sources, including ACC, the United Nations Environment Programme in Nairobi, and several other researchers working in this part of Kenya. With very minor modifications to the urban version of the model, ICE scientists adapted UPlan to model different land-use choices in rural areas of southeastern Kenya. They modified UPlan to work within the Kenyan policy framework by developing five land-use scenarios for the Mbirikani Group Ranch in the Amboseli ecosystem in Kajiado District, Kenya. California projections use urban variables, such as general plan boundaries, distance to freeways and major arterials, residential/commercial/industrial land uses, and employment statistics. UPlan for the Mbirikani region includes temporary/permanent/fenced *bomas* (living areas), distance from water sources and villages, suitability of habitat types for farming and grazing, and proposed locations of new conservation areas.

The output from five different Mbirikani scenarios, based on past trends, various degrees of fencing, and different management plans involving Mbirikani, will assist researchers and ultimately local ranch members with land subdivision decisions. Taking this one step further, ICE researchers combined the pattern of human settlement from each scenario with possible wildlife migratory routes modeled across Mbirikani. Not surprisingly, the results pointed to the scenario with the highest level of subdivision and fencing having the most detrimental effects on migratory patterns of zebra and wildebeest in a landscape connecting some of the world's best-known wildlife areas.

Maasai cattle raising dust in the South Rift region of Kenya.
(Photos: Karen Beardsley)

Californian city and county planners and Maasai group ranch leaders are not as different as one might think when it comes to interpreting maps and developing and evaluating alternative future scenarios. When applied to rural locations, such as southeastern Kenya, overlaying potential wildlife corridors with modeled future human habitation patterns using ArcGIS is a powerful method that can facilitate decision making in ways not previously envisioned. This study demonstrated the applicability of the UPlan model to rural Kenya and provided an example of how the model and its output can be used to evaluate different land-use options. Principal wildlife management stakeholders, including the local community, private conservancies, nongovernmental organizations, and the government, could work collaboratively (despite potentially opposing planning priorities) to determine a mutually agreeable way to plan for future uses of the land.

The goal in conducting this research was to develop the ideas and test the methods for applying UPlan in rural, group-managed lands in Kenya, recognizing all along that these methods and results should be taken back to the local people for their full value to be realized. The expectation is not that ArcGIS applications like UPlan be placed in the hands of Maasai herdsmen. Rather, local support organizations such as the ACC would manage the technical aspects of the process and work with local stakeholders to visualize and evaluate model results. ACC could operate the models, produce maps, and work directly with the local people using the Swahili or Maasai languages instead of English. An iterative process of developing alternatives, observing potential outcomes, and modifying parameters as needed to develop and evaluate new alternatives (following the geodesign paradigm) would keep people involved and engaged at all levels of the process. ACC has expressed a keen interest in moving forward with this work. The main obstacles, as is so often the case with international collaborations, have been time and funding.

It will be an informative experiment to take the next steps and make these methods and results available locally and see how they are used to support Maasai group ranch subdivision decisions.

About the Author

Karen Beardsley, PhD, GISP, has worked for the Information Center for the Environment, Department of Environmental Science and Policy, at the University of California, Davis, since its inception in 1994 and is currently the codirector of ICE together with professor James F. Quinn. She has a master's degree in geography from the University of California, Santa Barbara, and a PhD in geography from the University of California, Davis.

For more information, visit www.conservationafrica.org.

See also "How UPlan Works in California."

(This article originally appeared in the Summer 2012 issue of *ArcNews*.)

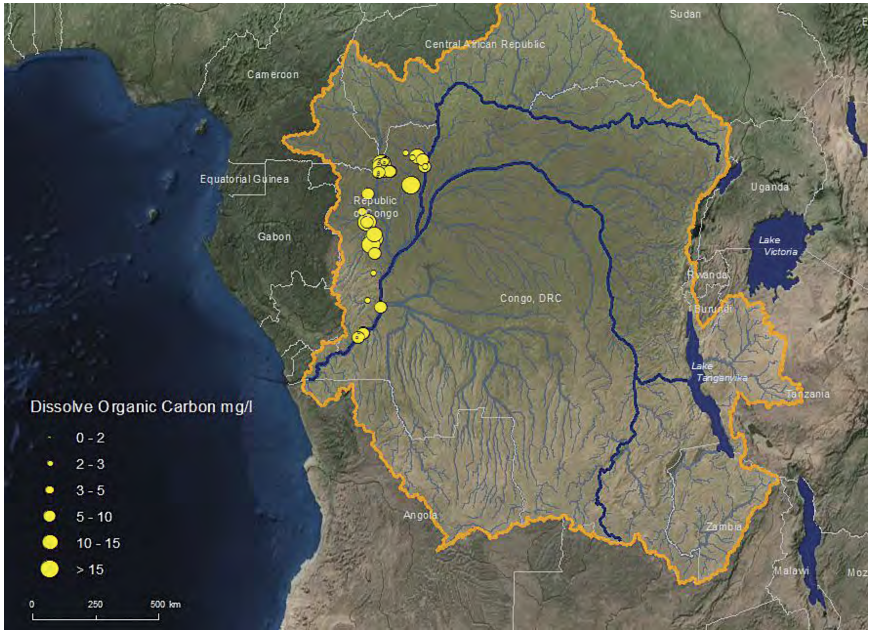
It Must Be Something in the Water

Exploring the Link Between River Chemistry and Land-Cover Traits in the Congo River Basin

Scientists from the Woods Hole Research Center (WHRC) embarked on an expedition to collect water data from the Congo River Basin, the world's second-largest river system and one of utmost importance for understanding the global carbon budget. Greg Fiske, WHRC's GIS manager and researcher, was part of the team. He was there, armed with vast quantities of spatial data, to ensure that the team stayed on the route during the expedition and to contribute to the sampling goals.

Supported by the National Science Foundation, the Global Rivers Project is a collaboration of several institutions around the world and focuses on six globally significant river systems: the Congo, Yangtze, Brahmaputra, Ganges, Kolyma, and Fraser. Fiske contributes his GIS skill and expertise to work with an array of scientists, including geologists, geochemists, hydrologists, engineers, and remote-sensing experts, to explore the relationship between river chemistry and large-scale land-cover characteristics.

Within the Republic of Congo, the team traveled by four-wheel-drive truck on a southwest–northeast transect, covering 1,400 kilometers (roughly the distance from Massachusetts to North Carolina) and enduring rough terrain, poor roads, insect infestations, and days of soggy weather countered by days of stifling heat. November is the rainy season in the Congo, which was the main reason the trip was planned for that time. High-flowing rivers and wetlands at their peak created an ideal contrast between the sampled water chemistry from this trip and that from previous excursions taken in the dry season.



ArcGIS was used to monitor dissolved organic carbon along the Congo River prior to and during this trip.

One of the key measurements was dissolved organic carbon (DOC), which is a general term for those organic components dissolved in marine and freshwater ecosystems. It is a key indicator of land disturbance and land-cover changes worldwide. As a doctor may take a sample of your blood to divulge information about the health and well-being of your internal systems, so too can scientists characterize the conditions of the land within a watershed by taking detailed chemical samples of rivers and streams. And DOC isn't alone. Scientists have an elaborate quiver of water chemical metrics that may define land-related changes within our world's major watersheds. In addition to DOC, water samples were analyzed for a variety of other constituents, including dissolved and particulate forms of nitrogen and phosphorus, as well as temperature, salinity, pH, and a selection of dissolved gases.

As with any statistical modeling, diversity is important in the sample set. GIS was used to find easily accessible major waterways where the areas of contribution (upstream watershed) covered the most diverse set of land-cover types available in the Republic of Congo. Latitude-longitude coordinates for each sample point were captured using Garmin GPS and mapped regularly.

The Congo River Basin has the largest swamp forest in the world. It is where the team spent the majority of time collecting data. Team members traversed these forests in a pirogue (wooden dugout canoe), sampling water along the way. Despite the

Over the side of a pirogue, researchers collect water samples in the swamp forest.

hardship of the journey, they were happy to encounter a variety of land-cover types: grasslands and croplands in the south; sparse forest areas in the nation's midsection; dense humid forests in the north; and, finally, swamp forests in the northeastern area of the country.

The team's goal was to collect data on each land-cover type in the basin, as well as samples from tributaries that feed those areas. In preparation for the trip, Fiske loaded spatial data onto his laptop, which the team used for indicating specific land-cover types that were important to the analysis. He also created some GIS scripts to assess the upstream area and produce a selection of land-cover metrics within that area based on key remotely sensed GIS layers.

At the end of each day, Fiske uploaded the geocoded water sample data to his laptop, running ArcGIS software. He overlaid water-sample and land-cover type attributes on the remote-sensing data so the team could immediately see the results of its work and affirm that it was in the appropriate location. On the fly, GIS brought together the sample points/locations and the spatial data. GIS displayed an area's tree cover, its biomass/carbon, high-resolution natural color imagery, and more. For the Congo area, important data layers include the percentage of swamp forest and seasonal inundation. (Other watersheds around the world may need different GIS data layers.)

Fiske also made good use of ArcGIS software's hydrology toolbox for a lot of the work on the project. This made work in the field easier. Using these tools and the custom scripts, at the river's edge, the team could click a button and query the GIS about the size of the upstream contributing area or the percentage of tree cover or other key land-cover types.

The challenge that made mapping difficult, and sometimes made fieldwork impossible, was the intense rain and the river waters. Fiske and other members of the team were constantly concerned about dropping gear into the river or losing it in the bottom of a flooded pirogue. Sensitive gear was protected in waterproof bags and hard cases. Data was backed up on a USB-powered external hard drive that was secured in a watertight case.

The team had other duties besides data collection. As part of the National Science Foundation grant, some project funding is designated for outreach and education. Building on a successful partnership with schools and communities in the Russian Arctic, the team visited schools in two communities in the Congo River Basin on this trip, and art supplies were distributed to the students. The children were asked to put pen to paper and describe, through art, the importance of their local river. Their pictures and drawings will become part of the My River, My Home exhibition, joining nearly 100 other pieces from students in Siberia and Canada. The exhibition will travel to galleries, and a virtual collection will be posted on the WHRC website.

In addition, the team worked with local people and trained them to collect water samples and metrics. This would allow the scientists to retrieve critical time-series information on the tributaries of the Congo. WHRC staff and partners worked with students, teachers, and community leaders who live in the towns and villages within watersheds, and they built partnerships for sustainable solutions.

Upon returning to the United States, the team provided data and samples to associates who would use them to further study the attributes and relationships within the basin. Collectively, the members hope to reveal just how important dissolved organics and other key elements can be in detecting the impact that humans have on the land of the Congo River Basin. Their findings will provide the basis for understanding the health of a watershed and directing future watershed management.

Fiske is currently the GIS adviser for the Global Rivers Project. Using tools such as ArcGIS Online, he has been able to share data with others and distribute commonly used base layers. He chose ArcGIS Online because it is free and user-friendly, so even those with no GIS experience can use it. He posts project-wide base layers—such as stream networks, sample locations, and watershed boundaries—to ArcGIS Online so that scientists and others can download maps and data directly into their own GIS projects. It is essential that the various river projects all use the same version of these layers. The ArcGIS Online map viewer is also used to make maps of sample locations and other important layers that are shared among colleagues.

Fiske and others are also designing spatial models to show correlations of certain land-cover types and water chemistry variables in hopes of being able to extrapolate the rules defined by the Congo analysis to other portions of tropical Africa—places that would be much more difficult to go to and physically sample.

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