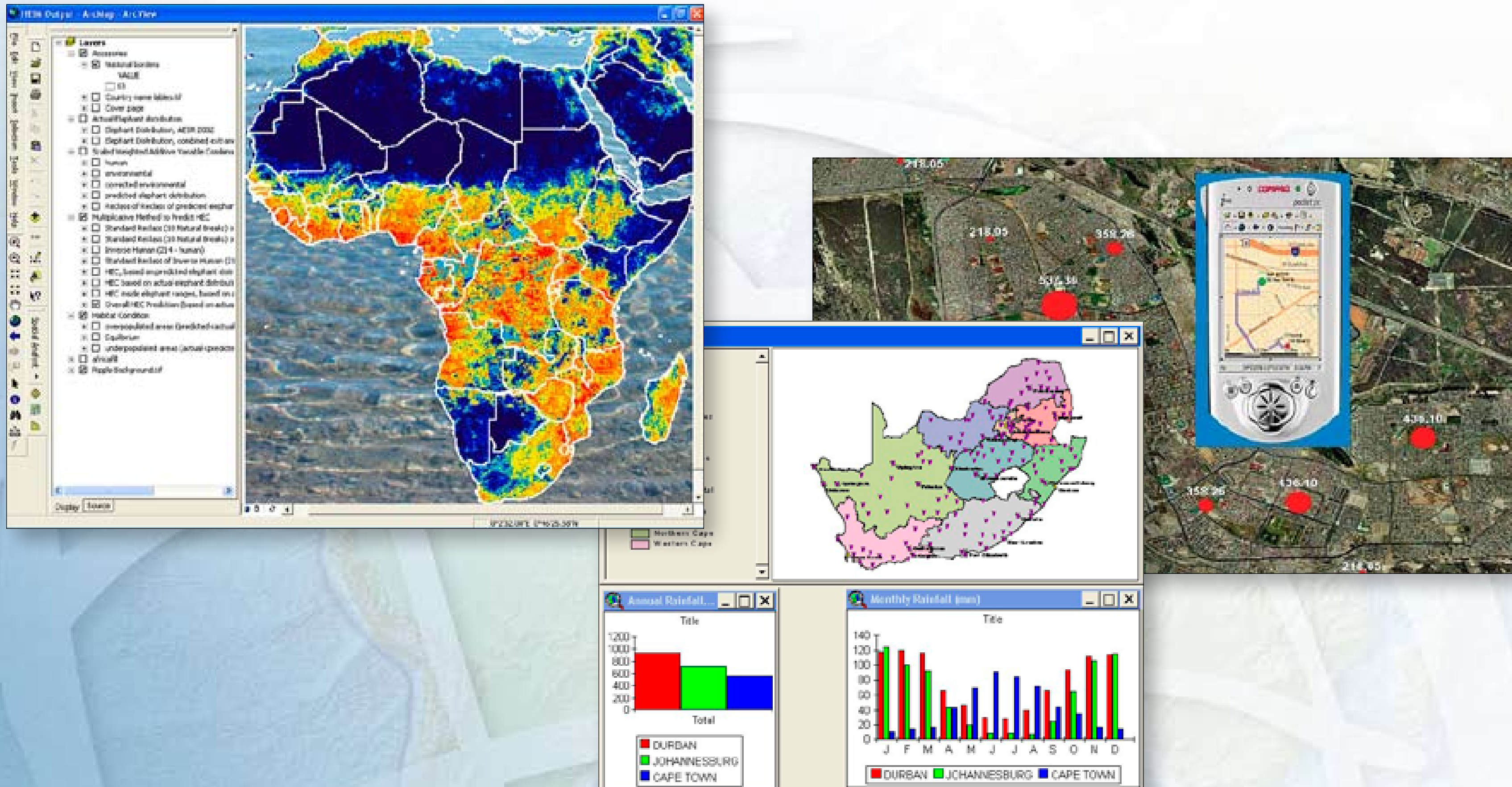
GIS Best Practices

GIS in Africa



March 2009

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What Is GIS?

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

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

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

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

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

Global Dialogues: GIScience and Sustainable Development in Africa

"Crossing Borders"
A column by Doug Richardson,
Executive Director, Association of American Geographers

The Association of American Geographers recently had the opportunity to participate with hundreds of African geographers, GIScientists, and environmental scientists in a new dialogue around the theme of Geospatial Science and Sustainable Development in Africa. These discussions, which were initiated in March 2008 and have already generated several promising new areas of research and educational collaboration, were sponsored by the U.S. Department of State's Global Dialogues on Emerging Science and Technology (GDEST) program. Follow-on activities and continuing interactions resulting from these dialogues have the potential to generate considerable ongoing and long-term cooperation among African and U.S. scientists in geographic research, geographic information science (GIScience) education and GIS applications, sustainability science, and many related fields.

Five other GDEST programs also have been undertaken, including dialogues in Japan (focusing on nanotechnologies), China (biotechnology), and Germany (quantum computing). However, the recent Africa GDEST program is the first to be initiated on a continental scale and the first to address geography-related research fields, such as geospatial science and sustainability.

The Global Dialogues on Emerging Science and Technology program focusing on Geospatial Science and Sustainable Development in Africa began in March 2008 with site visits to universities, governmental ministries, and nongovernmental organizations in nine African countries, followed by a conference on the same theme in Cape Town, South Africa.

The U.S. delegation was divided into two teams, East Africa and West Africa, and included members from the U.S. Department of State Humanitarian Information Unit and its Bureau of Oceans and International Environmental and Scientific Affairs, as well as representatives from other U.S. governmental agencies, several U.S. universities, the American Geographical Society, the Association of American Geographers, and the United States Agency for International Development (USAID) regional offices. The teams conducted more than 50 site visits and met with hundreds of African experts in the fields of environmental remote-sensing interpretation and modeling, GIS cartography and analysis, agriculture, education, health, surveying, mining, climate, hydrology, population, urban systems, and information and communication technology.

Care was taken to listen to and learn from our African colleagues, to identify needs rather than prescribe solutions, to build upon existing regional capacity in geospatial science and technology rather than duplicate or displace it, and to explore opportunities for collaboration between U.S. and African scientists and institutions, as well as among African organizations and networks, in ways identified as useful to scientists, educators, and governmental agencies from the region.

It was clear from both the country visits and the conference that significant progress has been achieved since the 2002 World Summit on Sustainable Development in terms of the diffusion and sophistication of geospatial technologies, applications, and coordination, both regionally and in individual countries, and their use in sustainable development planning and program implementation. Despite progress, however, optimal use of geographic information science and associated technologies is often constrained by a lack of resources, a lack of access to suitable data, and a lack of coordination among users and data producers.

Among other topics, GDEST participants particularly sought to promote future dialogues that would identify partners for collaboration on specific projects or programs; make better use of collaboration among U.S. and African scientists and practitioners to create a sustainable critical mass of African expertise; support regional and indigenous educational and institutional infrastructures; and develop educational and research collaborative mechanisms, including faculty and student exchange programs, online interactions, and better access to research and curricular information.

The AAG currently is implementing some of the above resource sharing and online interactive coordinative mechanisms through its new subsidized Developing Regions Membership Program and through the existing AAG Center for Global Geography Education programs.

Also important to sustaining collaboration is supporting existing African networks of excellence and platforms for dialogue, information sharing, and communication. For example, African networks of excellence, such as the African Association of Remote Sensing of the Environment (AARSE), African Geo Information Research Network (AGIRN), African Reference Frame (AFREF), Environmental Information Systems Africa (EIS-AFRICA), Mapping Africa for Africa, and university networks (e.g., University Network for Disaster Risk Reduction in Africa [UNEDRA]), are vital infrastructures of communication and coordination for research, education, and applications collaboration. Descriptions of and linkages to these and many other existing African networks can be accessed directly through the AAG Web site at www.aag.org/developing.

The U.S. GDEST delegation representatives, both individually and in coordination with U.S. embassies in the countries visited, are currently following up on contacts and acquaintances made during the site visits and will be continuing discussions on specific projects for which opportunities for partnerships and collaboration were identified. A report on the African GDEST program's progress and findings is under development and will be made available in the near future.

I would like to thank Lee Schwartz, director of the Office of the Geographer and Global Issues at the U.S. Department of State, together with Nina Fedoroff and Andrew Reynolds of the Office of the Science and Technology Adviser to the Secretary of State, for providing key leadership and logistical support essential to the success of the African GDEST program. Most importantly, on behalf of all of the participants, I would like to express our deep appreciation to our African colleagues for the opportunity to learn from them during these dialogues and for their insight and guidance on how to sustain ongoing interactions and useful collaborative activities in the years ahead.

More information on African geography and GIS research, education, and sustainable development activities, as well as collaborative needs and opportunities, is available and updated regularly on the AAG Web site (www.aag.org).

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

Cape Town's Emphasis on Systems Integration Exemplifies "Smart City" Goals

Highlights

- ERP and GIS optimize city's entire business processes through seamless IT integration.
- System is recognized as one of the world's largest local government ERP systems.
- City realizes substantial savings.

In 2001, seven neighboring local authorities were amalgamated into the City of Cape Town in the Republic of South Africa with the intention of consolidating and streamlining municipal services across the Cape Town metropolitan area. As a result of this massive restructuring process, the City of Cape Town, with a population of approximately 3.2 million, immediately became responsible for managing a number of antiquated, stand-alone information management systems holding disparate data in at least seven different IT centers across the new city.

Integrating its existing legacy systems into a seamless IT infrastructure became a top priority for the city. Committing itself to a holistic and comprehensive "smart city" strategy, the IT department initiated a number of projects to address the standardization of Information and Communications Technology (ICT) architecture and connection of constituent parts to enable a better flow of information among the departments and more efficient services for the city's residents.

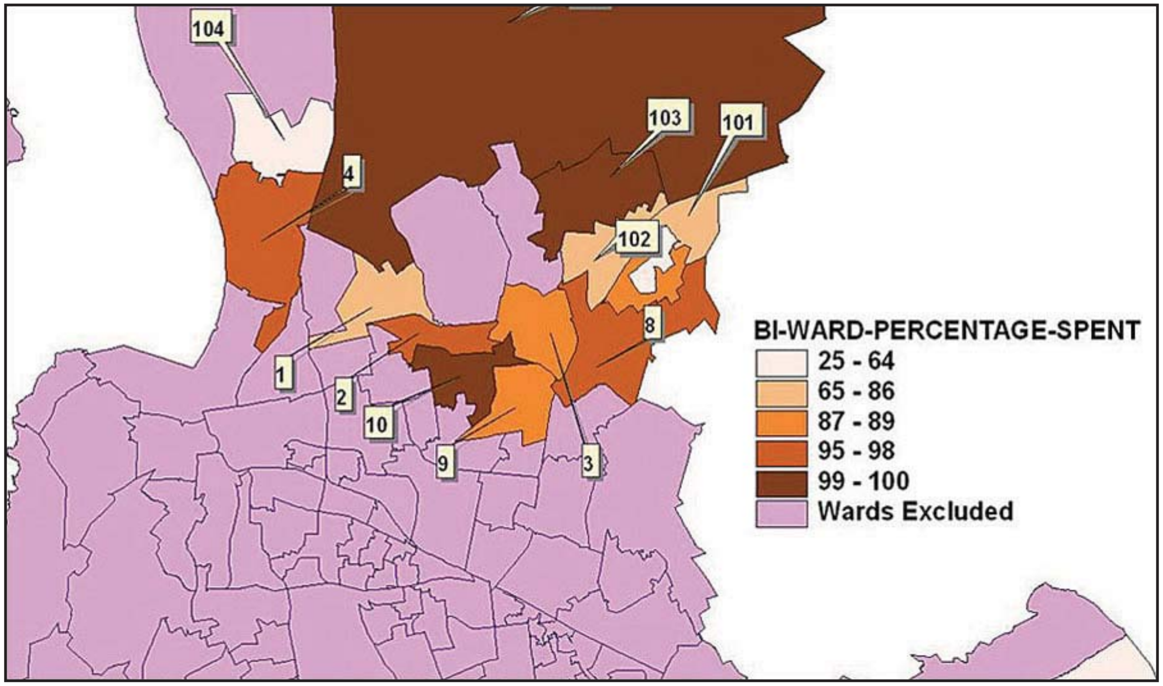
Key to the success of the smart city strategy was the implementation of the enterprise resource planning (ERP) system, which saw approximately 113 legacy systems and 70 interfaces replaced with a single functionally rich SAP solution designed to standardize and optimize the city's entire business processes. Recognized as one of the world's largest ERP systems ever implemented by a local government, it deploys SAP's Industry Solution for Utilities as the billing system to help streamline the revenue process and integrate these into the ERP back-office and CRM processes.

SAP is linked to GIS to extract monthly maintenance costs of water bursts in the Khayelitsha service area. Bursts have been captured with mobile GIS devices.

Next, the city integrated a GIS into the information system infrastructure. While GIS technology was used throughout the various local councils prior to the amalgamation, it functioned primarily as stand-alone systems with little standardization and limited compatibility. To reform this particular legacy, Cape Town implemented an enterprise GIS based on the ArcGIS platform. This allowed extensive functionality within a multiuser environment and provided an effective spatial data management platform for its many users. Initially, the city concentrated on consolidating electricity and property geodatabases into the GIS and subsequently added the Water Services geodatabase to the GIS process. Since then, a number of other departments, such as Planning and Valuations, have started implementing GIS technology. ArcGIS was successfully implemented in participating departments as the city focused on integration issues, such as user profiles, as well as standardized data capturing and maintenance of departmental geodatabases.

Cape Town's Water Services proved to be the ideal utility from which to continue its GIS integration initiatives. South Africa is located in a semiarid region without significant perennial rivers or lakes, and this reality requires extensive conservation and water control measures. The City of Cape Town also experiences a 3 percent annual growth in its population, placing an even greater strain on the city's limited water resources. Given these constraints, GIS provides one of the best possible means to collect, analyze, and model spatial data for optimization of water conservation and demand strategies.

The implementation of SAP enabled the city to establish an effective link between the system's business information capabilities and its location-based asset information, such as pipes, meters, reservoirs, treatment plants, and associated attribute data stored in GIS. By taking advantage of this linkage, Cape Town is now able to extract the monthly maintenance costs for incidents, such as burst pipes and sewer blockages, as well as to evaluate water consumption patterns based on tariff structures.



This shows the percentage of capital budget allocation spent for 2006 per selected wards.
The data originates from SAP Business Warehouse.

There is also a link to the asset register, which is a model that runs against the GIS infrastructure geodatabase and is used to calculate solutions, such as the life span of the various parts and components of the Water Services infrastructure. GIS can, therefore, be used as a tool to plan medium- and long-term budgeting of infrastructure projects, such as replacing pipe infrastructure due to increased population demands or end of life cycle redundancy. Next, the city will apply the lessons learned from the Water Services implementation to the development of a sewer and storm water geodatabase. Currently, the existing ArcEditor/ArcInfo tools are utilized for multiuser editing in eight district offices, but the long-term vision is to develop a customized editing tool within the ArcGIS Server environment.

By developing a common data model for GIS use throughout the city, the City of Cape Town has realized substantial savings in its operations and developed a GIS that promotes data sharing while minimizing data redundancy. The overall strategy is to implement a GIS completely integrated with the city's enterprise-wide information architecture and infrastructure, providing support to the city's private citizens and its local business community.

The Water Services Department has also implemented a Technical Operations Centre (TOC) that interfaces with the Corporate Call Centre to initiate operational responses and manage event tracking and logging. Currently, the Water Services Department is evaluating the available technology and interfacing options to develop a fully automated, spatially enabled event management system (EMS), defining an event as any operational activity requiring a response. The EMS would be used to monitor and support the responsibilities of the city's employees to increase their efficiency. For example, the EMS would automatically record the exact location of an event occurring in the city and analyze it to determine its impact on the surrounding area. Using location as a reference, the system would then identify assets the city has at any particular location and dispatch work crews to respond to the event. Workflows developed within the EMS will allow the city to define and manage its standard operating procedures to support the EMS. The workflows would analyze the system's automated response to an event and escalate the response to a higher level, demanding greater urgency, if required.

According to Pieta Le Roux, former GIS coordinator for the city's Water Services Department, because events will be spatially referenced, engineers will be able to interpret trends and patterns visually, which will allow them to be proactive in their response to events. In addition, the TOC will coordinate responses to water/wastewater emergencies by integrating the notification and work order processes of SAP with mobile GPS/GIS and communication technologies. This integration will allow the city's supervisory control and data acquisition

(SCADA) and telemetry systems' alarm components to be part of the central IT network and information infrastructure for quicker response to any malfunctions or anomalies occurring within the city's utility networks.

Le Roux further states that the City of Cape Town has a mature GIS, which is commonly viewed as central to the city administration's plans for a tightly integrated and service-oriented IT architecture, supported by a modern infrastructure, for seamless enterprise information management capability. The GIS production and geodatabase server environments form a major part of this integration process.

Commenting on the future, Le Roux says, "Cape Town will be implementing strategies and processes toward the transactional integration of GIS and SAP to provide the necessary life cycle views and real-time feedback of their asset maintenance environment."

(Reprinted from the Winter 2007/2008 issue of *ArcNews* magazine)

Early Warning Planning for Mosquito-Borne Epidemics

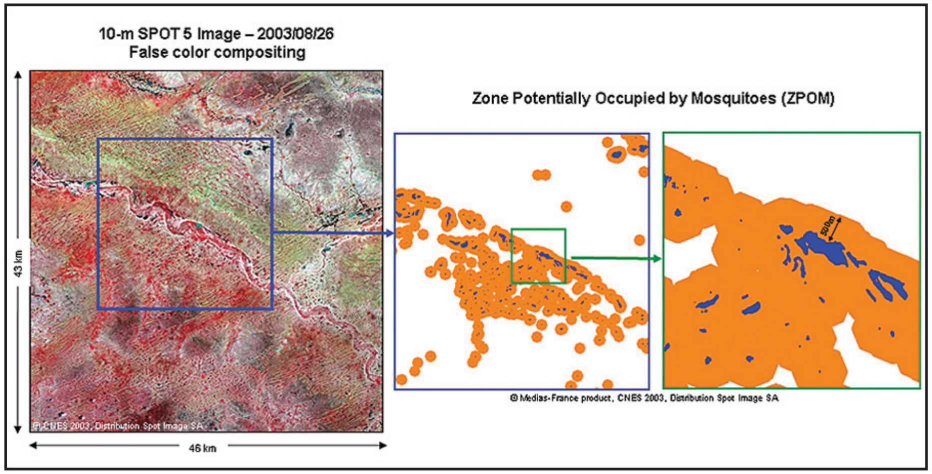
GIS, High-Resolution Remote Sensing Help Evaluate Degrees of Risk in Senegal

By Yves M. Tourre, Delphine Fontannaz, Cécile Vignolles, Jacques-André Ndione, Jean-Pierre Lacaux, and Murielle Lafaye

Highlights

- GIS tools and remote sensing were used to detect potential breeding ponds.
- In situ observations validated the indexes.
- Using ArcView, researchers calculated mosquito density and evaluated cross-potential risks

Fifty years of successful efforts in the prevention and control of infectious diseases and epidemics have inspired confidence and optimism in modern medicine and technology. Nevertheless, epidemics remain a conspicuous challenge to public health today. In the context of climate change and rapidly increasing population, some epidemics are even reemerging.



A false-color composite of a 10 m SPOT 5 image (left) and ENVI 4.3 software were used to obtain a new pond index (NDPI). From the NDPI, ponds (in blue) were precisely located (center and right). The 500 m zone potentially occupied by mosquitoes (ZPOM) is shown in orange.

For example, the Ferlo region in Senegal, Africa, became prone to Rift Valley fever (RVF) in the late 1980s when virus-carrying mosquitoes *Aedes vexans* and *Culex poicilipes* appeared. The latter species proliferate near temporary ponds and neighboring humid vegetation. RVF epizootic outbreaks in livestock cause spontaneous abortions and perinatal mortality. So far, human-related disease symptoms are often limited to flu-like syndromes but can include more severe forms of encephalitis and hemorrhagic fevers. As a result, local socioeconomic resources can be seriously affected.

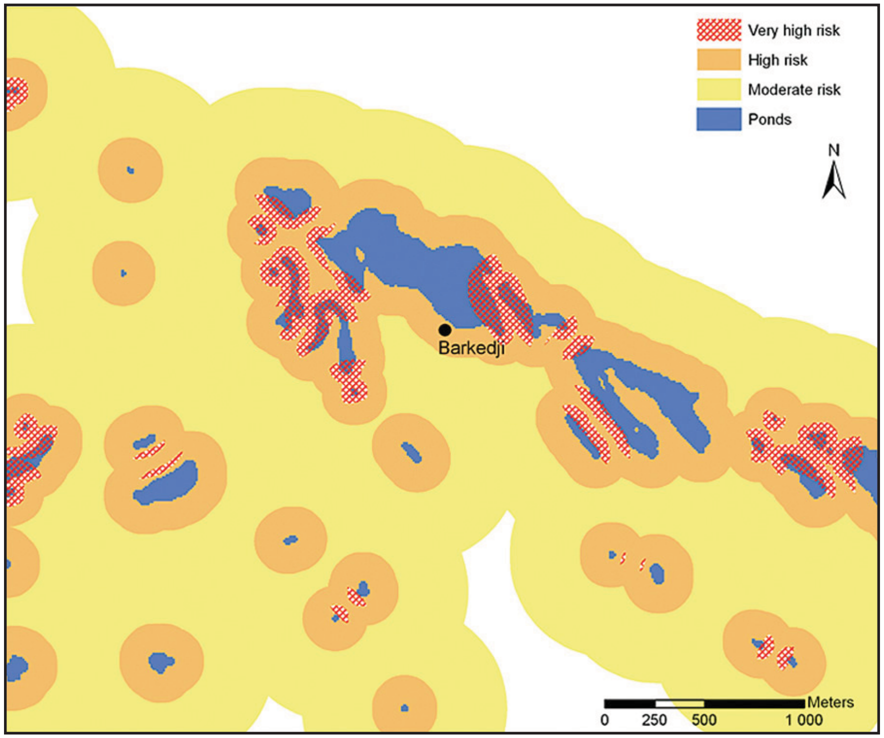
Professor P. Sabatier at the University of Grenoble indicated that this growing threat created an urgent need for a local early warning system (EWS) for RVF epidemics in Senegal. The goal was to use specific GIS tools and remote-sensing images/data to detect potential breeding ponds and evaluate RVF diffusion and areas with potential risks.

Project Description and Preliminary Methods

MEDIAS-France implemented the RVF project in the Ferlo region under the auspices of the French Spatial Agency (Centre National d'Etudes Spatiales). MEDIAS-France is a nonprofit corporation that coordinates research groups studying global environmental issues in areas including the Mediterranean Basin and subtropical Africa.

In the Ferlo region, the abundance of mosquitoes is linked to rainfall, ponds and their turbidity, and the presence or absence of vegetation in ponds (e.g., water lilies, wild rice). Initially, Environment for Visualizing Images (ENVI) 4.3 imagery processing software from ITT Visual Information Solutions was used for spectral analysis of high-resolution (~10 m) SPOT 5 images to locate the ponds. First, image registration tools were used to warp the images to match and implement relative georeferencing for all SPOT 5 images collected, with further adjustment to minimize spatial errors. Then, new indexes were obtained by using the classic Normalized Difference Vegetation Index (NDVI) transform tool to allow the combination of different spectral bands (such as the middle infrared [MIR] and the near infrared [NIR] red and green bands). The Normalized Difference Pond Index (NDPI) allowed detection of all ponds; the Normalized Difference Turbidity Index (NDTI) allowed the evaluation of water transparency or turbidity. In situ observations by participants from the Center for Ecological Monitoring (Centre de Suivi Ecologique) in nearby Dakar validated the indexes using GPS and GIS.

Using these methods, small ponds were located with precision, making it further possible to map RVF risks from zones potentially occupied by mosquitoes (ZPOM) following recent studies from entomologists on flying ranges and spatial distribution of mosquitoes.



ArcView conversion, data management, and analysis tools enable the display of an improved three-zone ZPOM for potential Rift Valley fever risks. The very high-risk zones are red-hatched to identify underlying pond limits.

GIS Methods

Further refinement and simplification were needed, however, because of the complexity of the pond distribution and to develop an effective usage strategy for local health information services. Researchers wanted to identify degrees of risk from isolated and/or clustered ponds, calculate the target risk coverage area, and evaluate risk by mosquito density in overlapping zones.

Because of researcher Delphine Fontannaz's GIS expertise and the availability of new detailed information in the zones, the GIS approach became an obvious solution for the team. Using ArcView software and tools (e.g., conversion and data management for spatial projection and transformation, as well as overlay and proximity vector data analyses), maps obtained from SPOT 5 10-meter multispectral resolution imagery were first transformed into appropriate formats, then converted from raster to vector formats. The georeferencing accomplished through universal transverse Mercator (UTM) WGS 1984 for zone 28N permitted further comparison and processing.

The initial ZPOM was first divided into three bands chosen for defining risk levels for potential virus transmission by Aedes vexans. Then, using ArcView software, researchers calculated mosquito density and evaluated cross-potential risks. They noted that zones with very high and high risks were inhabited by potential reservoirs, i.e., carriers (snakes, frogs, and toads), of the RVF virus and produced an improved ZPOM.

Results

The analyses using GIS technology allowed researchers to see that risks increase when ponds are close to each other. Using GIS technology, researchers created a new, more detailed, and more useful ZPOM. GIS tools provided new products and information for use by local early warning systems in the prevention of disease.

Future Applications

This technique might be improved by adding digitized ecological zone layers. Multidisciplinary users can benefit from this data by using it to choose strategic positioning of villages and parks according to RVF risks. This new methodology is also being transferred to other teams in Africa for varied types of mosquito vector research.

About the Authors

Tourre, Fontannaz, Vignolles, and Lacaux are affiliated with MEDIAS-France, Toulouse, France; Ndione is affiliated with the Centre de Suivi Ecologique (CSE), Laboratoire de Physique de l'Atmosphère et de l'Océan, Université Simon Fongang, Dakar, Senegal; and Lafaye is affiliated with the Centre National d'Etudes Spatiales (CNES), Toulouse, France.

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

Planning Education Projects in Rural Ethiopia Using GIS

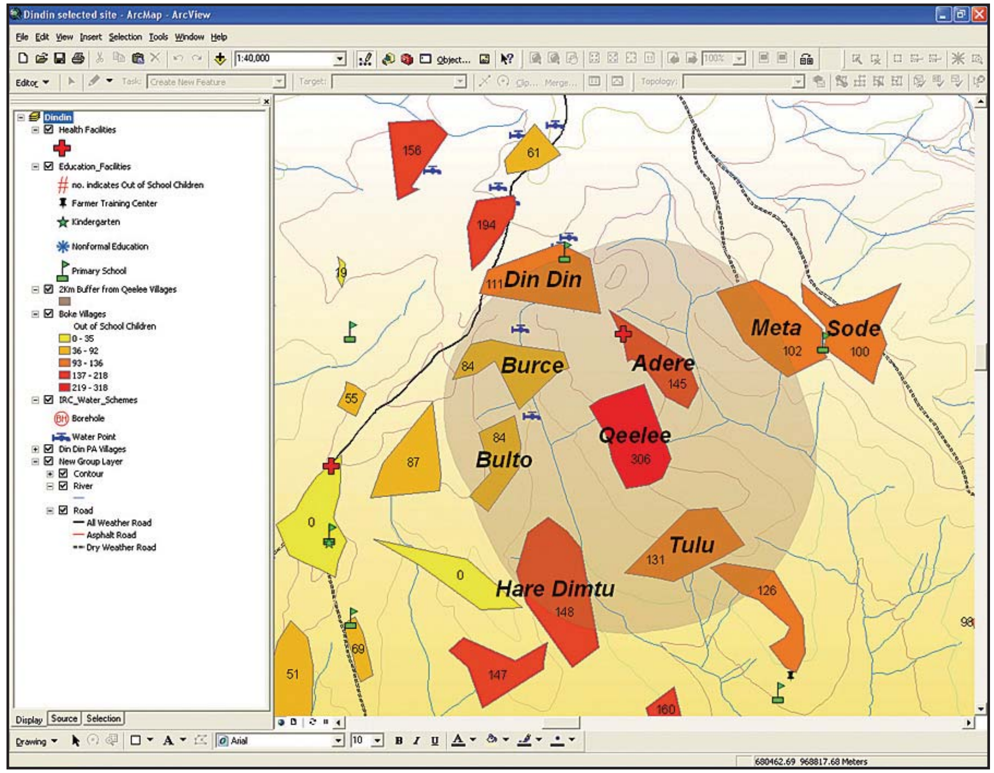
Highlights

- GIS technology maximizes the number of children reached.
- IRC Ethiopia has gained new insight into its development and relief programs.
- Success with ArcView software has led IRC Ethiopia to expand GIS into almost every project it undertakes.

Every day, millions of rural children in Ethiopia do not attend school. Instead, they work on farms; dig in mines; or perform strenuous household tasks, such as gathering firewood or fetching water, which together can take several hours each day. For them, education is out of reach, both because poor families require the additional income and because many areas lack elementary schooling altogether.

Beginning in 2005, the United States Department of Labor funded the International Rescue Committee (IRC) to build schools and train teachers for community Alternative Basic Education (ABE) schools, which would serve as institutions to transition children from the labor force into more formal educational institutions, such as primary schools. Simultaneous community awareness and education programs promoted the benefits of education and encouraged families to send their children to school.

In implementing the project, IRC wished to use the funding as effectively as possible. The first task was to locate each new ABE school within walking distance of as many out-of-school children as possible. Second, because the ABE program is designed to prepare children for more formal schooling, it was decided that each new ABE school should be within two kilometers of a formal primary school so that graduates of the ABE program could easily transfer to the formal school system. One further constraint on the program was that proposed school sites should be relatively near main roads in order to facilitate the construction process and program monitoring.



Map of villages in Boke Woreda, Ethiopia, that displays the number of out-of-school children in each village. Maps such as this were used to site new Alternative Basic Education schools/centers near the most potential students and near extant primary schools in the area. Based on this analysis, Qeelee was chosen as the site for a new school.

The Ethiopian Education Office lacks the infrastructure and funding to maintain information on primary school locations, village school age populations, and distances between schools and village populations. Low-level road maps are also not available for most rural districts. The IRC Ethiopia program therefore had to build its geographic database from the ground up. Behar Hussein, the IRC Ethiopia GIS coordinator, trained eight people in the use of Garmin eTrex Vista GPS units to aid in the survey of 491 villages. The surveyors used Garmin eTrex Vista GPS for the survey. While four of the eight surveyors gathered geographic data about village boundaries, roads, health centers, water points, and primary school locations, the remaining four gathered demographic data from each village: the number of households, number of children of each age, and number of children of each age attending formal schooling. The data took more than 50 days to collect and was cleaned and compiled at IRC's Addis Ababa office.

"It was much harder to obtain this data than downloading it," laughs Hussein, who performed the analysis using the office's ArcView program. He focused on children aged 6 to 11 years of age who were not enrolled in formal schools. First, he plotted the number of children not in school in each village; that map displayed several obvious locations for ABE schools that would be in close proximity to large numbers of out-of-school children. Of those locations, not all were within the proposed two kilometers of the nearest primary school. Potential locations were further narrowed down by their access to roads, which were extensively mapped out during the village surveys.

IRC constructed ABE schools at 22 sites in each of the four selected rural districts, each site chosen to be close to a large number of children not already enrolled in school. Each ABE school was also within two kilometers of a government primary school, ensuring that the program and its graduates were integrated into Ethiopia's educational institutions. The proximity to usable roads meant that the construction could be carried out in a timely manner and that IRC could easily monitor the progress and enrollment at each ABE site. Following the construction of the 22 ABE schools and with continued funding from the U.S. Department of Labor, there are currently 4,120 children enrolled in the Alternative Basic Education program and preparing to enter more formal schooling. The program is currently expanding enrollment to vocational training for older youth. By enabling these children to further their education instead of laboring, the program improves their individual economic opportunities while simultaneously furthering the development of Ethiopia as a whole.

The obvious utility of ArcView analysis in this project's success means that IRC Ethiopia has expanded GIS into almost every project it undertakes, from developing project proposals to coordinating activities with other international organizations and from planning the sites of health centers to building new water points in refugee camps. IRC Ethiopia's extensive use of GIS has given it new insight into how and where to implement its development and relief programs.

"I think this is just a great example of efficient planning during project implementation," says David Murphy, the country director for IRC Ethiopia. "We used GIS tools to maximize the number of children reached by our program, ultimately putting our funding to its best use."

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

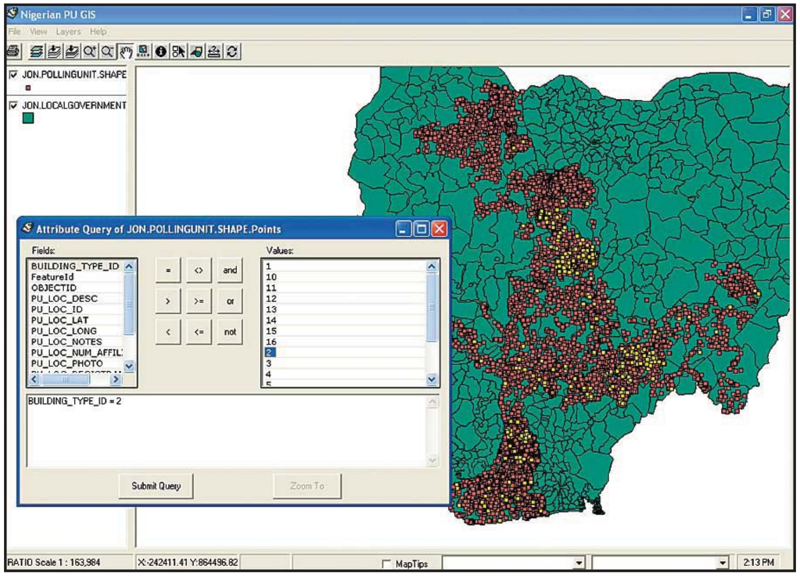
Nigerian Voting System Modernized

GIS Prevails Despite Unnavigable Terrain and Political Unrest

Highlights

- 120,000 polling locations are inventoried and spatially located.
- System helps ensure free and fair elections in Nigeria.
- GIS is used for map production and redistricting.

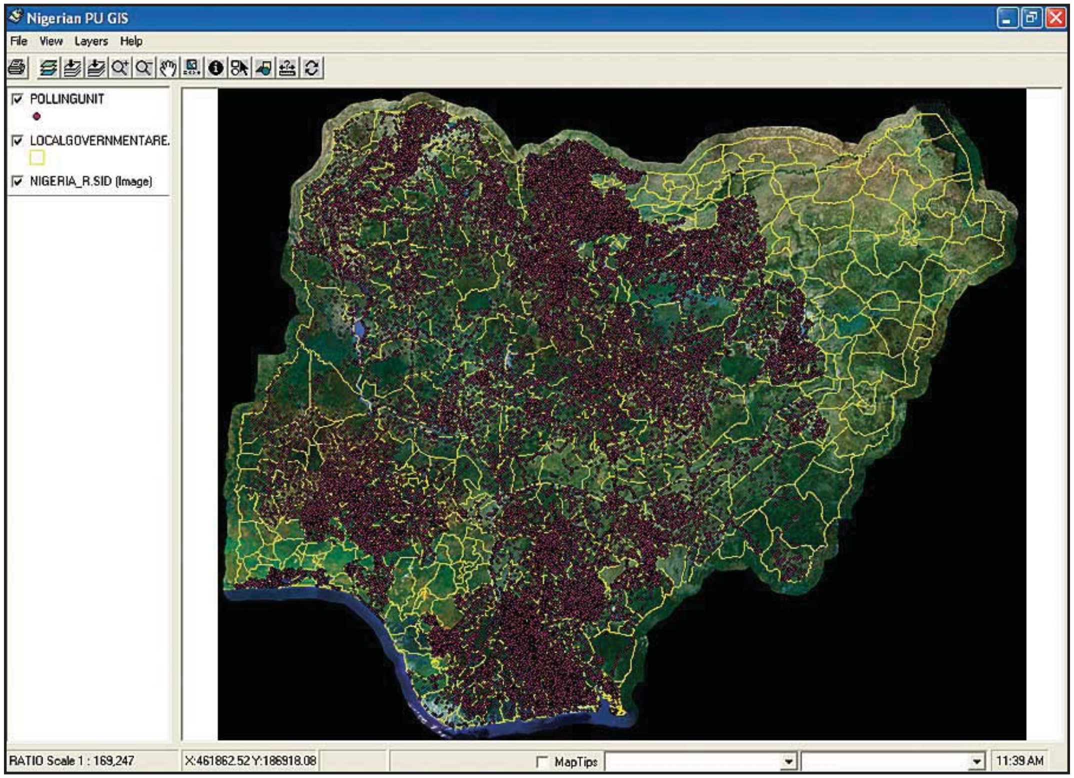
Nigeria, one-third larger than Texas in area and the most populous country in Africa, is located on the Gulf of Guinea in West Africa. It is bordered by Niger and Chad to the north, Cameroon to the east, and Benin to the west. The lower course of the Niger River flows south through the western part of the country into the Gulf of Guinea. Swamps and mangrove forests border the southern coast, while inland are hardwood forests.



The project was carried out in three phases: development of the data collection application, field data collection and editing, and development of the Polling Unit GIS application.

The Independent National Electoral Commission (INEC) is a nonpartisan Nigerian government agency charged with the conduct and supervision of elections. In the late 1990s, the agency began modernizing its information technology infrastructure by migrating from an outdated legacy voting system heavily dependent on inaccurate paper records and polling cards to the newer Electronic Voting System (EVS). At the heart of EVS is the Electronic Voter Register (EVR), which, by capturing the names of all eligible voters, eliminates duplication and thereby minimizes discrepancies in the electoral process. As such, EVR is viewed as a means of ensuring free and fair elections in Nigeria.

As part of the modernization process, INEC needed to inventory and spatially locate the agency's 120,000 polling locations scattered around the country. These locations and their attributes needed to be linked to EVR.



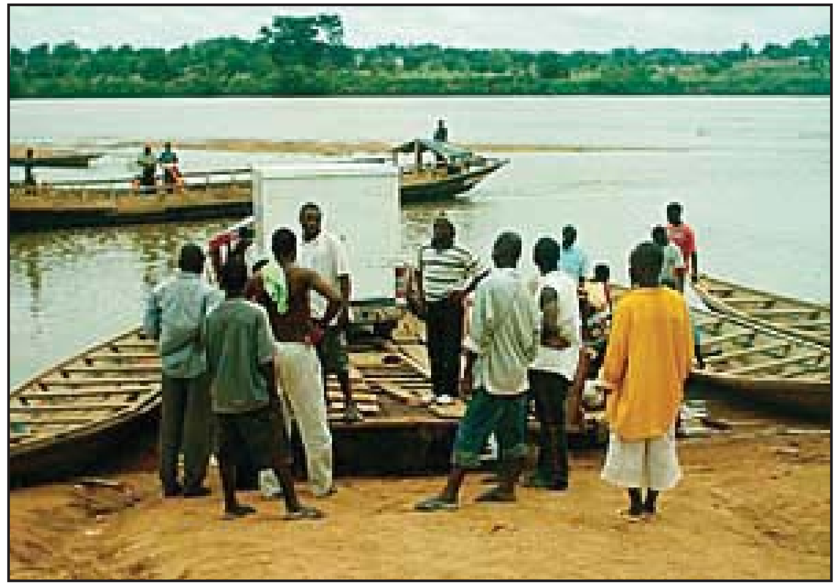
GIS technology was identified as a potential solution to the problem, and TTi Limited (formerly Adorbel Ltd.)—a consultant responsible for the field data collection and project management for INEC—subcontracted to ESRI Business Partner Geo-Imaging Consulting of Washington, D.C., to design and implement a Polling Unit (PU) GIS. Geo-Imaging proposed integrating GPS, digital photography, and DBMS technologies to create a data collection tool capable of capturing the x,y locations and images of existing polling units. Since the client's budget constraints precluded the purchase of COTS GIS software, the use of an industry-standard development environment to create an application with GIS/mapping capabilities was also proposed. The application would then be linked to EVR.

The project was carried out in three phases: development of the data collection application, field data collection and editing, and development of the Polling Unit GIS application.

The data collection equipment comprised 40 Dell laptops, Trimble Navigation GPS units, USB drives, and digital cameras. Each laptop was preloaded with a Microsoft Access database containing polling unit information from EVR. Using Trimble Software Development Kit, the GPS unit was customized to interface with the Microsoft Access application, allowing for the capture of each polling unit's x,y location and image directly into the Access database.

For the data collection exercise, the country was divided into four zones, each with a team of 10 trained field data collectors. At the end of each data collection day, USB drives were used to transfer data from the field laptops to servers in each zone's headquarters, after which the data was periodically transferred to the nation's capital, Abuja. Every week, the Abuja data was consolidated and transferred to Geo-Imaging's Washington, D.C., office where ArcGIS Desktop was used to convert and edit it. Mock registration areas (proposed third-level administrative boundaries) were digitized based on certain attributes of the polling unit data.

The PU GIS, a MapObjects software-based application developed using Visual Basic, displayed polling unit locations within two levels of administrative boundaries (state and local government areas) and the proposed registration areas. Apart from displaying data, the application also displays a given polling unit's image when it is identified. Users can also create simple GIS queries using the application, which is a client to an ArcSDE 9.2/Oracle DBMS.



During the course of the project, INEC commissioners visited Washington, D.C., for PU GIS end user training, as well as introductory GIS courses from ESRI. The final training session was carried out in Abuja after the testing and acceptance of the application. The audience at this session comprised largely the proposed end users.

Nigeria's Information and Communications Technology (ICT) Department established a well-equipped GIS lab on INEC's LAN and now uses PU GIS for departmental map production and future administrative boundaries redistricting decision support. The application is also used to generate reports and carry out analysis on voter distribution. ICT offers day-to-day support for end users of the application.

(Reprinted from the Summer 2007 issue of *ArcNews* magazine)

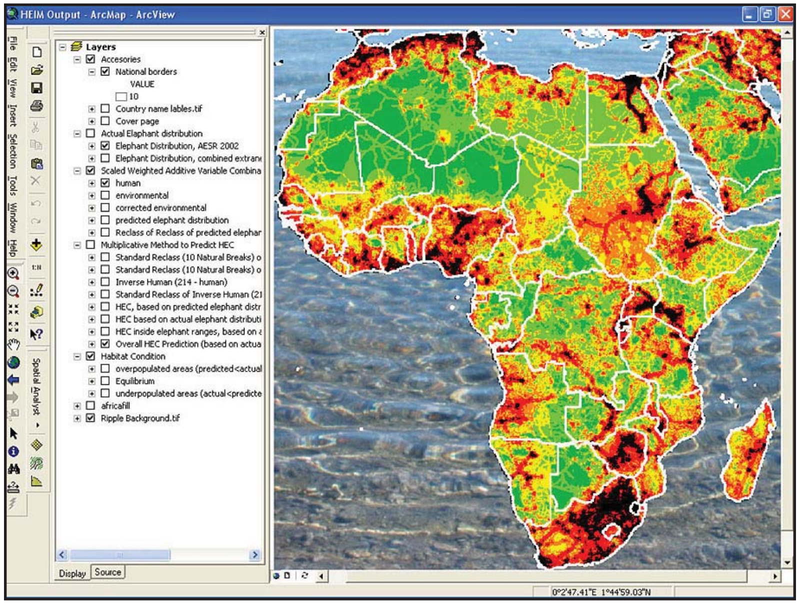
Helping Elephants Across the African Continent with GIS

With adults measuring up to four meters high and usually weighing more than six tons, African elephants are the world's largest land mammals; yet in all their magnificence, their history is tainted by a constant battle for survival. Poaching, the most recent of the species' troubles, is estimated to have decreased the African elephant population from 1.3 million in 1970 to just 600,000 by 1989. However, research conducted at the University of Southampton, England, is revealing a brighter future.

Elephant family group, Botswana, 1998 (photo courtesy: Martin Shipton).

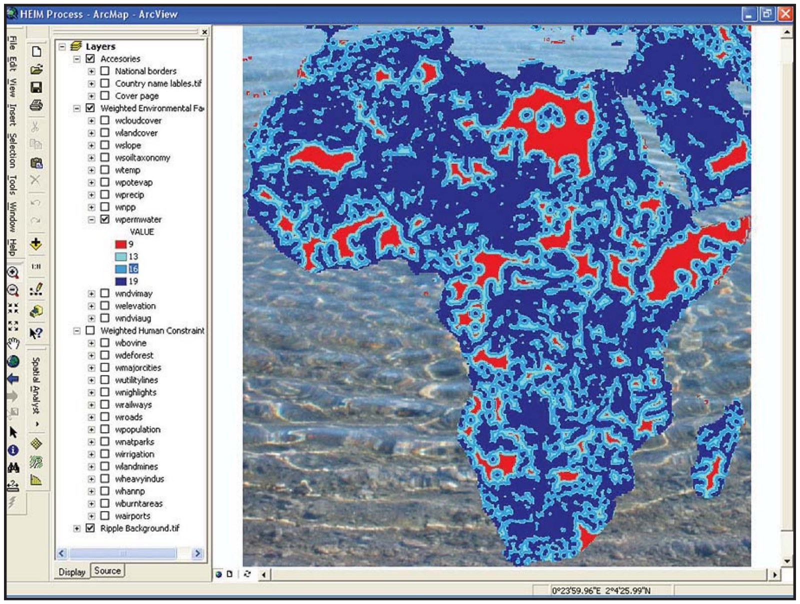
Over the last century, the human population on the African continent has dramatically expanded and subsequently sprawled into previously uninhabited areas. This has meant elephants and people have increasingly come into direct contact as their spheres of influence overlap. Consequently, conflict between humans and elephants has also increased as each species brings about land-cover changes undesirable to the other. As such, environmentalists have long recognized the need to manage this developing human–elephant interactivity. However, much of this management has focused on a local or, at best, regional scale. While seemingly effective, it neglects the holistic dynamics of the problem and often just transfers the trouble elsewhere.

A pioneering new approach to resolve this predicament is emerging from work conducted over the past year by Matthew Shipton, a researcher at the University of Southampton. The result of this work is the Human–Elephant Interaction Model (HEIM) that predicts the spatiality of human–elephant conflict across the entire African continent. While the results do not have the spatial resolution of more local studies, they have revealed previously unknown trends that can be directly traced back to land management policies. The model also acts as a decision support system, leading those in authority to make decisions that will be effective on a long-term basis. For example, HEIM can provide a list of the most suitable relocation sites for specific problem herds, which can only be done with a model of significant geographic scope since elephant ranges span up to 500 square miles.



Model prediction of combined human constraints.

HEIM is constructed in ArcView since it requires a wide range of geostatistical and spatial analytical tools to form the foundation of the spatial modeling and geoprocessing operations that are at its core. The ArcGIS Spatial Analyst extension was used in the development of the model, which is based on two datasets, both of which are primarily sourced from the American Geological Institute's Global GIS Database: Africa CD-ROM. The first dataset is a series of 12 carefully selected variables that attempt to outline the environmental characteristics of elephant ranges. This data ranges from remotely sensed normalized difference vegetation index calculations to slope maps to those detailing the distance to the nearest permanent water source. The second dataset is slightly larger (15 variables) and contains information on the human constraints that are imposed on an area's environmental suitability for elephant habitation. For example, this dataset includes data on human population density; land mine risk; and the location of national parks, major roads, and various industrial activities, including data on sustainable farming of both a pastoral and agricultural nature.

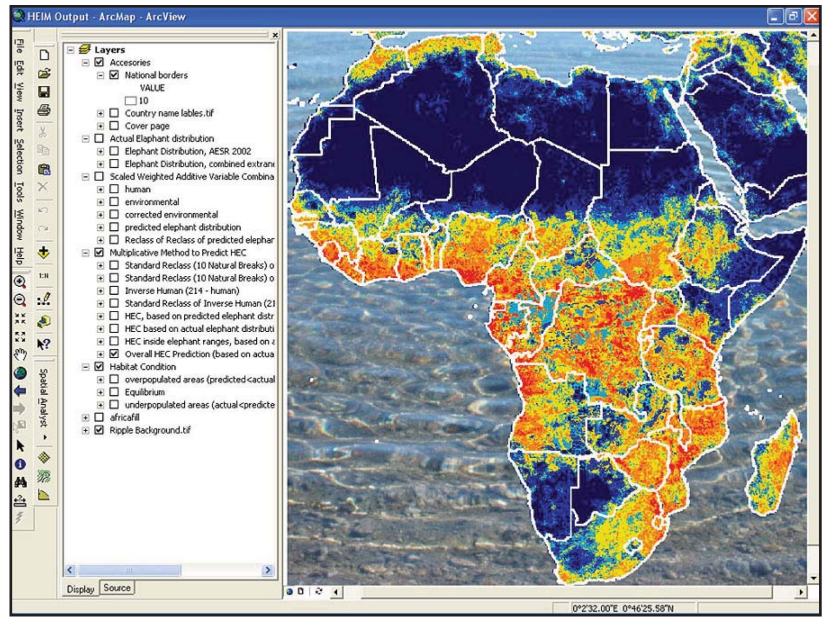


Distance to permanent water.

The variables in these datasets are independently weighted by a multiplicative matrix. This accounts for the varying magnitudes and intensities of the variables' impacts on elephant habitation. Moreover, because the variables are not all from the same source and the data they contain is collaborated in different ways, the matrix also gives some weight with regard to the accuracy, quality, completeness, age, and longevity of the data. Finally, the variables are calibrated with data from the African Elephant Status Report (2002), which was provided by the African Elephant Specialist Group. Known as "model fitting," this process emphasizes the importance of those variables that statistically best describe the actual distribution of elephants across Africa.

The two datasets are then separately combined with the raster calculator function in ArcView using the ArcGIS Spatial Analyst extension to create two base images: one shows the suitability of the African environment to elephant habitation and the other shows the severity of human constraints that limit elephant habitation. These images are then overlaid, again using the raster calculator, in a way that does not bias the greater number of variables in the human constraint dataset, to create an image that predicts the spatial distribution of elephants across the whole continent (assuming that elephants occupy the areas that have the most suitable physical environment and the lowest level of human activity). This image is then correlated with the data from the African Elephant Status Report on the actual distribution of elephants as a form of model validation, giving an idea of the accuracy of the model's output.

Once this is found to be acceptable, the severity of human–elephant conflict across Africa is calculated within specific error margins. This is done by again combining the two base images in ArcView but this time with the human constraints inversely scaled so the output gives the highest values to areas environmentally suitable for elephants with high levels of human activity. As a final form of model validation, ground control points were chosen across this image. These then had their relative level of human–elephant conflict confirmed or refuted through field observations by the charitable organization Living With Elephants and the Department of Geography and Environmental Sciences at the University of Zimbabwe.



Model prediction of human-elephant conflict.

With the data collected, a final step was then taken to analyze the overall condition of the African elephants' range. This was done by reclassifying the predicted elephant distribution and actual distribution into 10 natural breaks. The raster calculator was then used to identify where the predicted value exceeded the actual value (overpopulated), where it was beneath the actual value (underpopulated), and where the two were equal (a population in equilibrium). This provides a further tool for environmental managers, since knowing the degree to which an environment is stressed has numerous significant consequences on the way it is managed.

The model has been extensively tested and compared to proven ground data. The wealth of information contained within the model is now being analyzed so it can be used to further the effectiveness of conventional management projects. This analysis will provide a basis from which stakeholders can get a preliminary overview of the impact of specific management decisions. Moreover, it is desired that the model's spatial predictions of human–elephant conflict will be used as a foundation for national and intergovernmental strategic and tactical decisions regarding preemptive management to quell potential conflict zones—ultimately leading to a better life for African elephants.

(Reprinted from the Spring 2005 issue of *ArcNews* magazine)

South African Educators Teach GIS—With or Without Computers

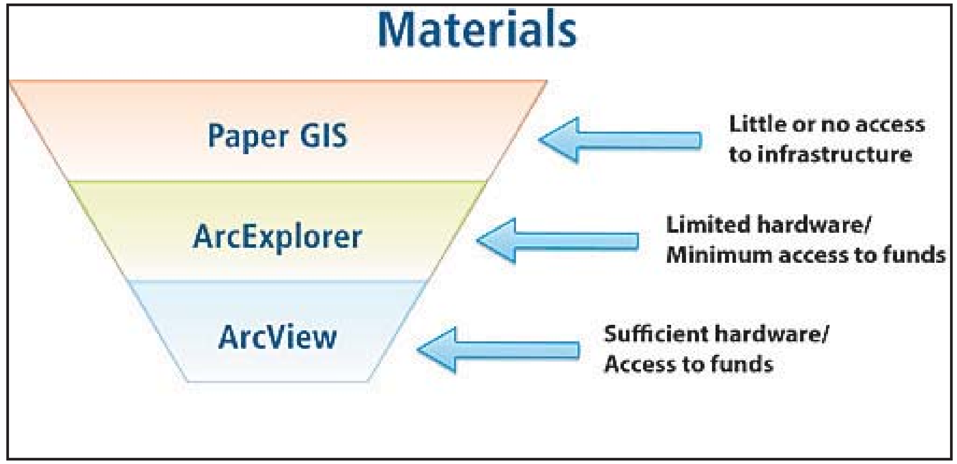
Huge Differences Exist Between Urban and Rural Schools

Highlights

- Department of Education includes GIS in secondary/senior school curriculum.
- "Paper GIS" was developed for schools lacking computer resources.
- ArcExplorer and ArcView are provided to schools with computer access.

The paper GIS targets those schools with no computer access at all.

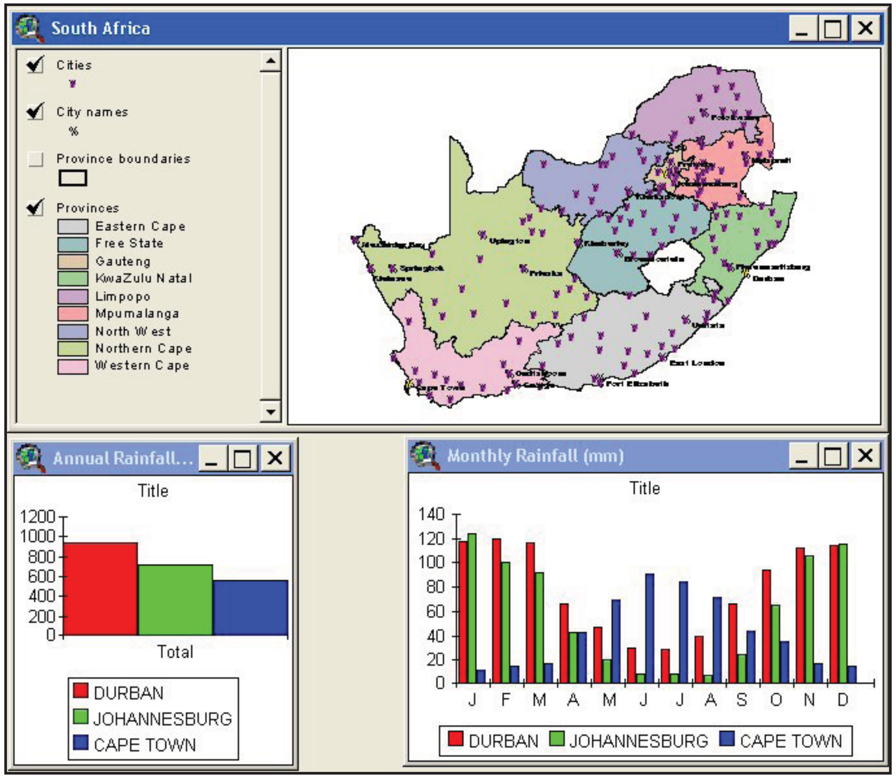
The South African National Department of Education included GIS in the curriculum for the first time in 2006. The introduction of GIS is taking place as a phased approach over the last three years of secondary/senior school. South Africa is divided into nine provinces, each with its own Provincial Department of Education. The Provincial Departments are overseen by the National Department, which is responsible for strategy and implementation, as well as training of senior curriculum advisors. It is, however, up to the Provincial Departments to ensure that all schools are introduced to GIS via the curriculum advisors in their respective provinces. The inclusion of GIS was met with apprehension by the educators, as most of them had not heard of GIS and there was a lack of skills for imparting this knowledge to the students.



Huge differences exist between schools in the rural and urban areas with rural schools lagging behind in resources, such as well-qualified teachers and access to electricity, infrastructure, and funding. These limitations needed to be addressed when material was being developed.

Day 2 introduced computers and ArcExplorer, and on day 3, the curriculum advisors were trained to use ArcView.

The government relied heavily on the private sector to facilitate the introduction of GIS. GIMS (Pty) Ltd. (the ESRI distributor in South Africa) took the initiative to assist and approached former geography teachers and other key people to guide the development of educational material. Complete GIS materials were developed to address the full spectrum of GIS educational needs in the Department of Education. The new GIS school materials include three separate approaches corresponding to the fundamental steps for learning GIS: namely, paper GIS, ArcExplorer, and ArcView.



Seasonal Rainfall in South Africa.

All materials are based on ESRI technology and terminology, as they provide the most appropriate and cost-effective GIS software tools to deal with the various levels of resources available to schools.

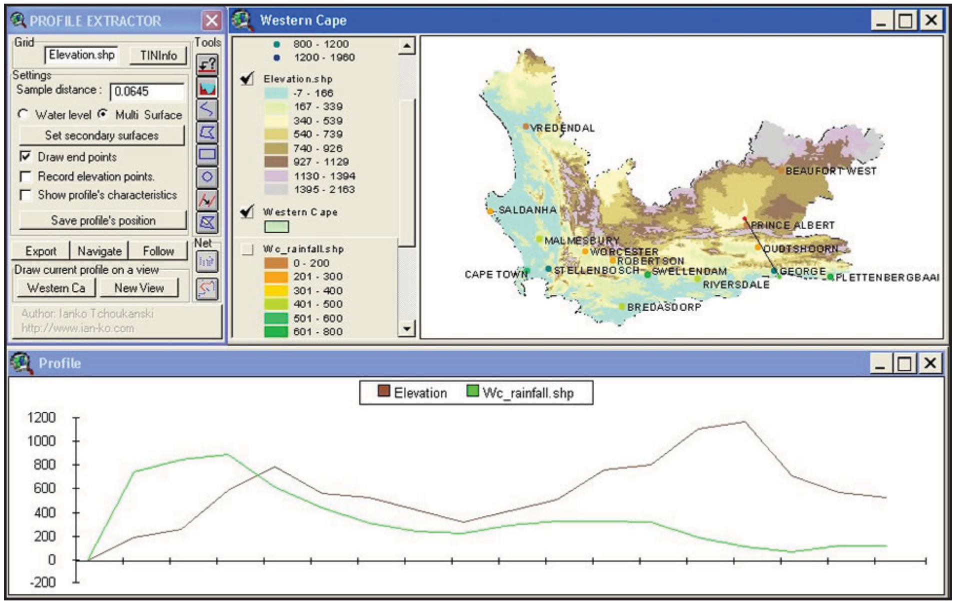
Scenic visuals of tourist attractions in South Africa.

The paper GIS was developed in collaboration with the Department of Land Affairs and the University of Pretoria. Paper GIS targets schools with no computer access. ArcExplorer satisfies the needs of schools that have limited access to computers (a single computer in a school), and ArcView addresses all GIS requirements that might be needed for schools with access to computers. Included with all three is fundamental training, covering the basics of GIS theory and relevant software knowledge.

Three-Day Training Course

At the beginning of the year, curriculum advisors countrywide were flown or driven to GIMS's Midrand offices to attend a GIS training course. As curriculum advisors have schools with different levels of computerization under their supervision, the National Department of Education decided to expose curriculum advisors to all three—paper GIS, ArcExplorer, and ArcView. Approximately 100 curriculum advisors attended the three-day training over a period of three weeks.

Day 1 saw the facility transformed into a training center for schools with no GIS computer facilities. Curriculum advisors were given a simple GIS task to complete with the aid of maps (courtesy of the Department of Land Affairs), crayons, and tracing paper. The task involved searching for the best location to evacuate residents in the event of a flood. This paper GIS proved very important for teaching conceptual issues of GIS before moving to the computer.

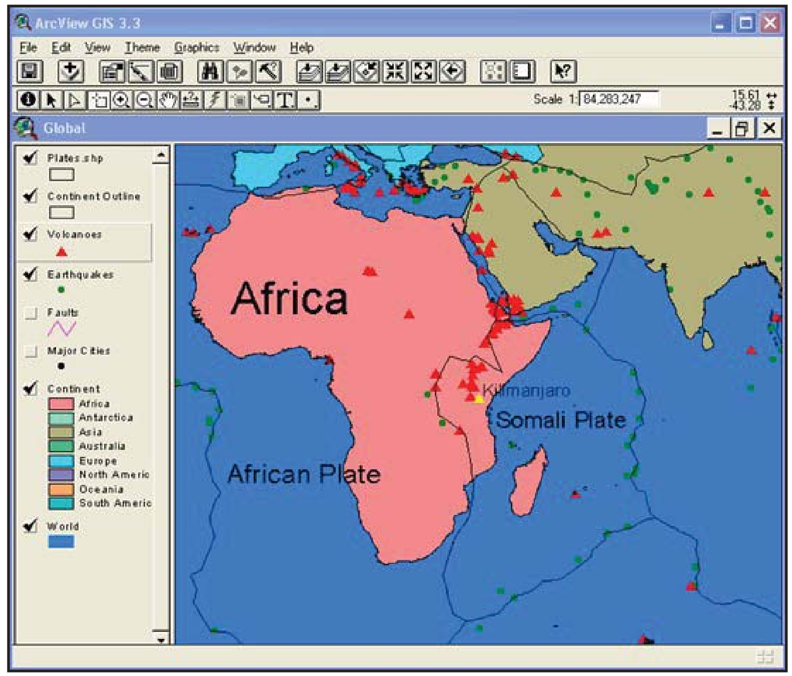


Cross-section from George to Prince Albert, showing the relationship between elevation and rainfall.

"The most important thing I learned was how to help my poorer schools—those without computers—to do GIS," says Ntobe Peter Ndima, senior education specialist, Nkangala region, Mpumalanga. "I am happy they will not be left behind."

Day 2 saw the introduction of the computer and ArcExplorer, and for some, this was their first experience working on a computer. The lessons were basic enough to eliminate the fear of the machine.

On day 3, the curriculum advisors were trained to use ArcView, helping them better teach geography where there is computer support. ArcView allows students to design their own research projects and to follow through with the investigation process, eventually producing maps and answering spatial geographic questions.



View of Africa showing the plates and incidence of Volcanoes and Earthquakes.

Praise for the Program

"The instructor has assisted us a lot in enabling us to deal with the GIS concepts, which we initially feared; especially the use of computers." —Mr. David Modisane Letlape, Curriculum implementer, Nkangala Region—Mpumalanga

"Fears were allayed—there was no difficulty." —Mr. Lungile Silo, Curriculum advisor, Confimvaba District—Eastern Cape

"Outstanding basic training. Most useful geographical workshop I've ever attended in my six years as a Curriculum advisor." —Ms. Penelope Liknaitzky, Curriculum advisor, EMDC Central Metropole—Western Cape

"First GIS course I enjoyed from day one until day three. The course kept my attention." —Ms. Rozelle Smith, Curriculum advisor, Eden Karoo District—Western Cape

"The material prepared for us is excellent to keep one going as far as GIS in schools is concerned." —Ms. Nomabhele Mzimba District, Subject head, Sisonke District—Mpumalanga

"The most important thing I learned was that GIS is not something beyond my and many educators' reach. We can do it—given the time to train and practice." —Mr. Wessel Potgieter, Subject advisor: Geography, Teaching and Learning Services, Vryheid—KwaZulu Natal

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

Ghana Project Leverages GIS-Based Title Registration and Microfinance to Alleviate Poverty

By Peter Rabley, International Land Systems, Inc.

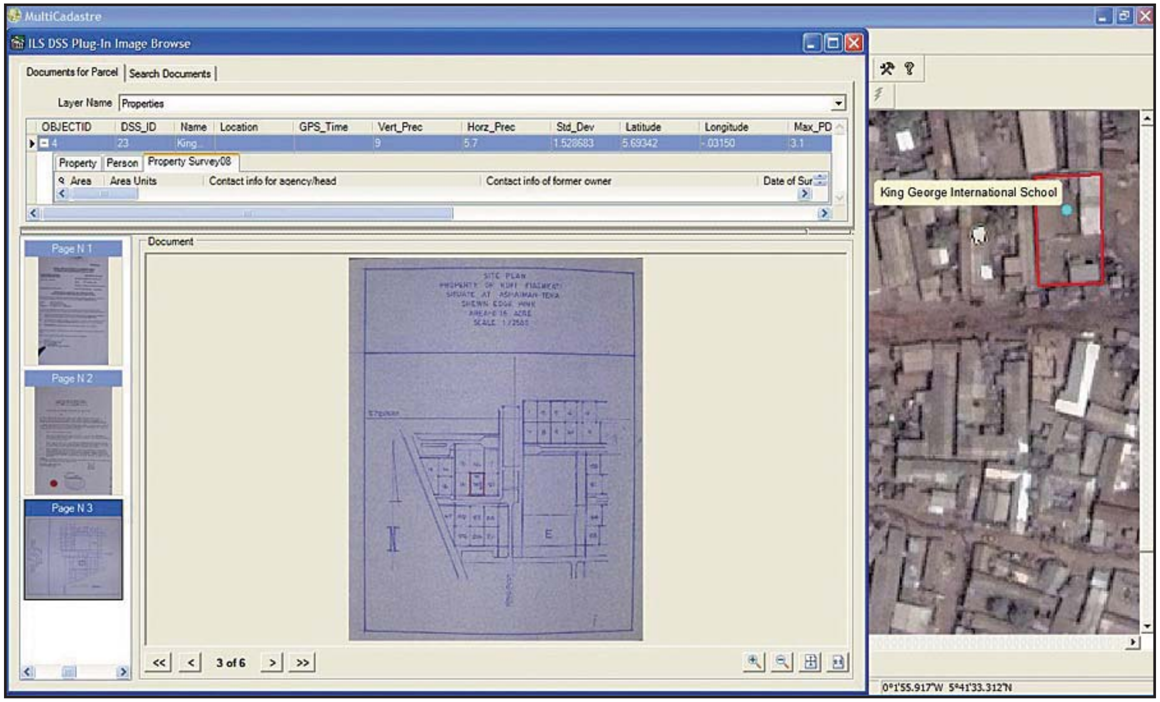
Highlights

- The project was presented to the United Nations Commission on the Legal Empowerment of the Poor.
- System incorporates ArcGIS functionality to link title information with the digital parcel map.
- Title and parcel data for loan processing is batched and provided to the ministry.

This article is part one of a multipart series.

A pilot project under way in the African nation of Ghana seeks to demonstrate the vital role that formalization of landownership can play in helping the poor take a crucial first step away from poverty. Focused on one of the poorest areas in the capital city of Accra, the pilot is leveraging the latest geospatial technologies to create a land titling process and GIS-based land records system where neither existed in the past.

Impetus for the Ghana pilot comes from the Clinton Global Initiative (CGI), started by former U.S. president Bill Clinton to challenge some of the world's leading organizations and individuals to make commitments that positively impact global health, poverty, climate change, and education. Accepting the CGI challenge to work toward alleviating poverty was First American Corp., a major title insurance and real estate information provider based in Santa Ana, California.



Using ILS MultiCadastre, all surveyed schools can be viewed. The ILS document scanning system plug-in allows for documents and images associated with each property to be examined as well.

With an extensive background in land titling, Craig DeRoy, then president of First American, embraced the economic theories described by Dr. Hernando de Soto in his acclaimed book The Mystery of Capital. The Peruvian economist is among the first to identify and describe the relationship between the formal recognition of property rights and the fight against poverty. DeRoy saw the CGI challenge as an opportunity to put de Soto's ideas into action.

With several partners, DeRoy presented the concept of a pilot project to the United Nations Commission on the Legal Empowerment of the Poor, which seeks to "make legal protection and economic opportunity not the privilege of the few but the right of all." The project received immediate feedback and encouragement from the commission's cochairpersons, Madeleine Albright and de Soto.

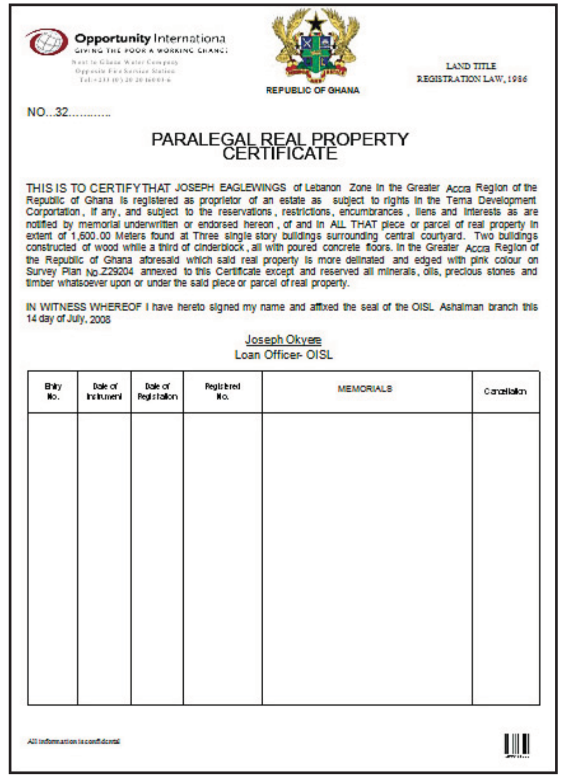
"Government recognition of landownership [through land titling] gives the poor an identity, which yields numerous benefits," says DeRoy. "The land title can ultimately be used as an asset to leverage permanent change in their economic and financial futures."

According to de Soto, poor people almost everywhere in the world have one thing in common—the only asset they have is the land they occupy. Unfortunately, very few of these people have ever received any type of legal recognition that the land is theirs, especially in situations where the ownership is informal or based on customary forms of tenure. Without a registered deed, title, or lease, the owner cannot leverage the land as collateral to take out a loan that might be used to start a business or improve the property.

From an economic perspective, this untitled land represents trapped capital that could be accessed to stimulate the local financial market with microfinance loans and mortgages. But gaining access to this hidden capital requires the landowners to have formal titles or deeds to their properties.

De Soto's research revealed that the benefits of formal landownership extend beyond the monetary value of loans and mortgages and provide another crucial stepping-stone out of the hopelessness of poverty. A land title gives a person an address, often for the first time, which dramatically improves that individual's sense of identity. As a result, the impoverished enjoy a greater feeling of security that their land won't be taken away and that they can improve the property. People with land titles are more likely to put their children in local schools and demand basic services from the government.

Despite these benefits, land titling and registration are out of reach for most of the poor. The process itself may be too daunting for governments to implement in poverty-stricken areas where no property mapping has ever occurred. And even in countries where titles and deeds do exist, the procedure may be too complicated, expensive, and time-consuming for low-income people to consider. As a result, the capital remains locked in the land, the local economy suffers, and the poor have no way out of their poverty.



Opportunity International
GIVING THE POOR A WORKING CHANCE

REPUBLIC OF GHANA

LAND TITLE
REGISTRATION LAW, 1986

NO...32...........

PARALEGAL REAL PROPERTY CERTIFICATE

THIS IS TO CERTIFY THAT JOSEPH EAGLEWINGS of Lebanon Zone in the Greater Accra Region of the Republic of Ghana is registered as proprietor of an estate as subject to rights in the Tema Development Corporation, if any, and subject to the reservations, restrictions, encumbrances, liens and interests as are notified by memorial underwritten or endorsed hereon, of and in ALL THAT piece or parcel of real property in extent of 1,600.00 Meters found at Three single story buildings surrounding central courtyard. Two buildings constructed of wood while a third of cinderblock, all with poured concrete floors. In the Greater Accra Region of the Republic of Ghana aforesaid which said real property is more delinated and edged with pink colour on Survey Plan No.Z29204 annexed to this Certificate except and reserved all minerals, oils, precious stones and timber whatsoever upon or under the said piece or parcel of real property.

IN WITNESS WHEREOF I have hereto signed my name and affixed the seal of the OISL Ashaiman branch this 14 day of July, 2008

Joseph Okyere
Loan Officer- OISL

Entry No.	Date of Instrument	Date of Registration	Registered No.	MEMORIALS	Cancellation

All information is confidential

The ILS DSS system allows for the creation of a paralegal title based on information gathered during the interview process.

Assembling the Team

First American and CGI clearly understood the benefits of land titling and in 2006 agreed on a commitment for the U.S. company to develop a template for cost-effective, in-country creation and maintenance of a land record system that ensures a means for establishing and holding the legal title to a property. To lead this project beyond the original commitment, DeRoy took early retirement and formed a new company called Corporate Initiatives Development Group (CIDG).

"In creating the land record template, the challenge was not in developing it, but in actually implementing it and making it practical," says DeRoy. "There had been much historic debate on the effects of formalizing landownership for the poor, but little had been done to bring these theories to market. I believed it could be done if the right individuals and companies could be engaged, leveraging years of experience and intelligence in land and technology issues to put together a process that could be made simple."

He sought to extend the CGI commitment to include an in-country pilot implementation. To make the pilot a reality, CIDG assembled a team consisting of International Land Systems, Inc. (ILS), Opportunity International, Trimble Navigation, and ESRI. Each provides a capability vital to the development of a practical land record system:

- ILS, an ESRI Business Partner in Silver Spring, Maryland, is implementing its commercial off-the-shelf GIS-based land recording and registration system, the key deliverable in the pilot.
- Opportunity International of San Diego, California, is a nonprofit microfinance lender already active in Africa.
- Trimble Navigation of Sunnyvale, California, is providing handheld mobile GPS devices that are being used to map the parcels in the field.
- ESRI is supplying core technology, in addition to managing the land surveying and mapping activities to create a parcel map, for the land registry database through Sambus Company Ltd., ESRI's international distributor in Ghana.

Selection of Opportunity International as a partner in the pilot highlights the important role that microfinance can play in the alleviation of poverty through formalized land titling. Historically, microfinance has focused on lending relatively small amounts of money—$50–$500—to individuals for use in starting in-home businesses. A sewing machine, for instance, can allow a woman to make and sell clothing in her neighborhood. Usually based on short-term paybacks, these loans are often made in trust groups so that peer pressure, not collateral, is the incentive for repayment. The result is a repayment rate of more than 95 percent on microfinance loans worldwide.

"Microfinance brings capital to these emerging markets in a very responsible way," explains DeRoy. "The creation of micro-entrepreneurs is a proven approach to the transformation of entire communities. In our project, we move microfinance one step further by placing Opportunity International, the microfinance lender, into the position of acting as a trusted broker for its clients seeking land registration. This use of the private sector serves to initiate, simplify, and accelerate a process that is often stymied by overwhelming governmental procedures and bureaucracy."

In recent years, microfinance lenders have been looking to expand their reach by loaning larger amounts of money for a variety of uses beyond entrepreneurial business, but this type of lending often requires an asset to be offered as collateral. More often than not, these lenders experience the other side of the situation described by de Soto. They want to loan money to the poor, but the only asset is untitled land, which can't be used to secure the transaction.

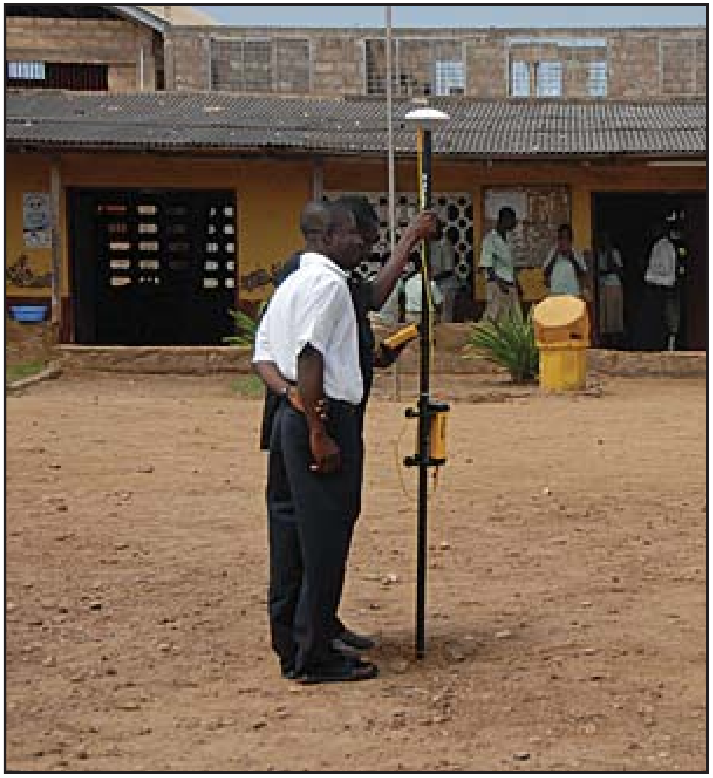
This oft-repeated scenario provided Opportunity International an incentive to facilitate land titling as a means of growing the potential market for its microfinance product offerings.

Targeting Ghana's Schools

In 2007, the participants chose a very poor area known as Ashaiman on the outskirts of Accra, Ghana, as the pilot location. Ashaiman is home to about 400,000 people in a 40-square-kilometer region where most of the structures can best be described as shacks and shanties. It was considered ideal for the pilot because Opportunity International is actively involved in microfinance there and had already been considering developing loan programs for the hundreds of private schools located in the area.

Operation of private schools is a growing business in Ghana, and the owners are seeking funds to build additional facilities and accommodate more students. From a mapping perspective, the schools were appealing for the pilot because the boundaries of their land are usually well defined. The decision was made to target only private schools in the initial pilot, because they presented the best opportunity to demonstrate the mutually beneficial link that can be made between formalized land registration, microfinance, and poverty alleviation.

Although the Ashaiman pilot is being conducted in close cooperation with the Ghana Ministry of Lands, Forestry and Mines, the project is relying solely on private funds. In this case, the fees associated with land titling will be rolled into the cost of processing the loan, so there will be no up-front transaction expense for the school operator to register a title. Economies of scale in processing multiple titles are expected to reduce costs significantly as the land registry becomes operational.



Ghanaian surveyors perform a cadastral survey of the property boundaries as described by the occupant, as well as neighbors.

Implementation of the pilot began in March 2008, and land titling had been completed for more than half of the 51 private schools in the pilot zone by August. This adjudication process, which will be described in technical detail in subsequent issues of *ArcNews,* involves surveying the school property with GPS-based mobile GIS equipment, creating a legal description of the land, and collecting property ownership information from the school operators and neighbors via personal interviews conducted by members of the local team. Each school owner has sought to become part of the land registration pilot and actively participated in the required procedures as part of the loan processing.

As the interviews and fieldwork are completed, ILS is uploading the data into its parcel-based MultiCadastre package, an off-the-shelf product that incorporates ArcGIS functionality to link the title information with the digital parcel map. This system is already managing the entire title registration process and workflow in a fully automated environment. For the pilot phase, this system will be maintained at the Sambus office and will generate paralegal land titles that will be provided to the participating schools for use in securing private loans.

The term *paralegal title* is used to indicate that the titling process has been initiated for acceptance by the private sector to jump-start microfinance activities. This commitment from the private sector is designed to give the government of Ghana the confidence to use the paralegal titles as the starting points for official title processing in the public land registry.

While the overall aim of the Ghanaian project is to continue to rely on private-sector entities to perform the land surveying and title recording work in support of microfinance work, participants are simultaneously assisting the government in modernizing its land titling and cadastral capabilities with many of the same GIS-based systems being implemented in the pilot. All title and parcel data collected for loan processing is batched and provided to the Ministry of Lands for its own land registry, which the team believes will be among the world's most technologically advanced.

According to DeRoy, this project demonstrates the true effect of what is called the "leapfrog factor." Given the rapid pace of technology development, those who come to implement a system of land registration today and are not burdened with existing infrastructure or bureaucracy can gain the maximum benefit from streamlined and cost-effective new processes while leveraging proven solutions.

"It is terrific that microfinance has matured to the point of being accepted as a traditional banking solution for the emerging markets of the world," says DeRoy.

About the Author

Peter Rabley is president of International Land Systems, Inc., with more than 20 years of experience designing and implementing land information systems around the world.

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

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

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