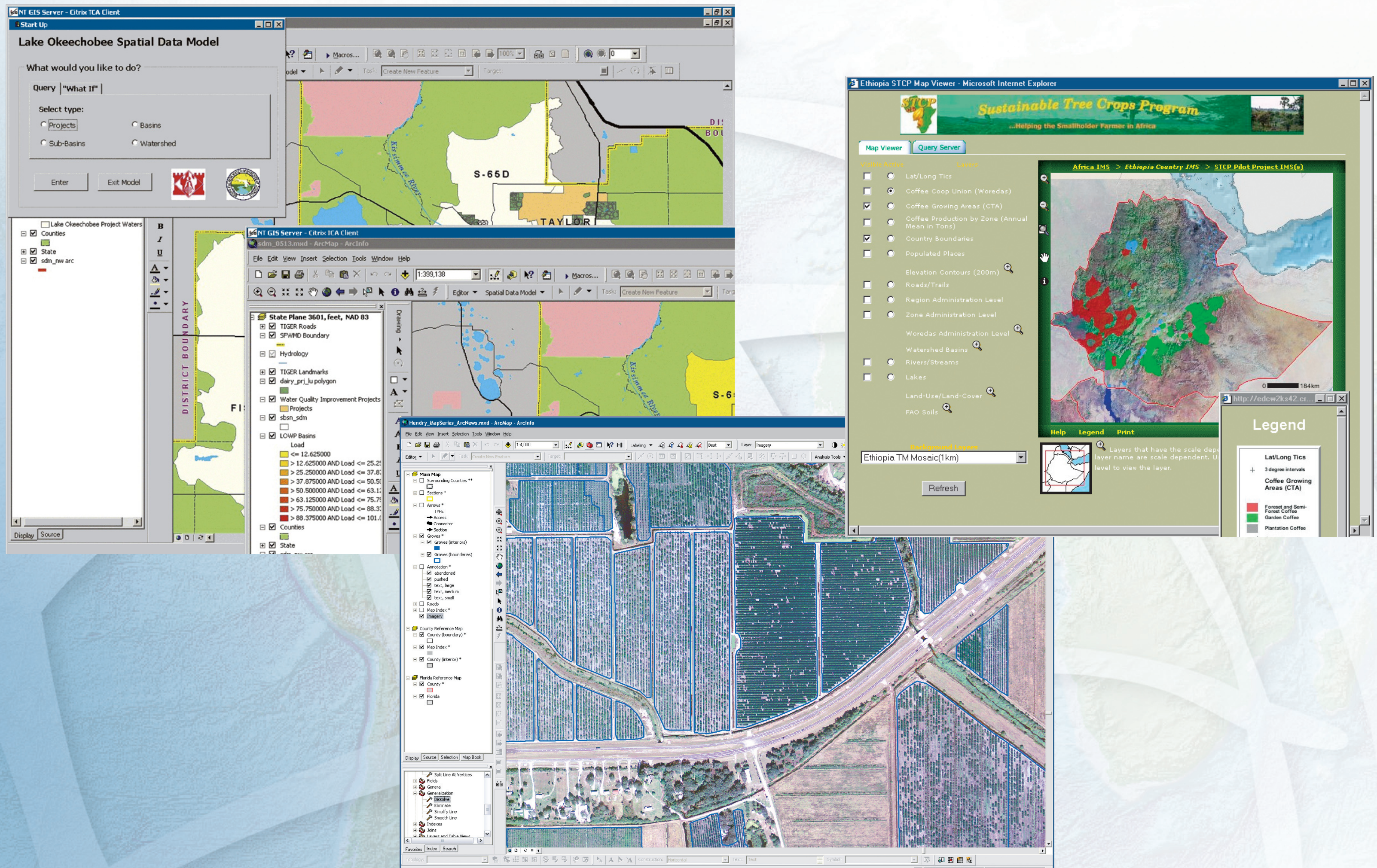
GIS Best Practices

GIS for Sustainable Agriculture



September 2008

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it look 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.

GIS for Sustainable Agriculture

Providing the current population and future generations with an indefinite food supply is an economic, environmental, and social concern. Geographic information system (GIS) technology enables community planners, economists, agronomists, and farmers to research and devise practices that will enable the sustainability of food production to ensure the survival of the human race. Whether implementing organic farming methods, finding the most profitable and healthy places to plant new crops, or allotting farmland for preservation to secure future food production, GIS has the capabilities to collect, manage, analyze, report, and share vast amounts of agricultural data to aid in discovering and establishing sustainable agriculture practices.

People working in agribusiness use GIS software for precision farming, land management, business operations, and much more. GIS provides the means to spatially view variables that affect crop yields, erosion and drought risk, and business opportunities. Farmers are now able to access online agricultural data from government services such as the USDA's soil assessment data or NOAA's weather and climate data and integrate it into their mapping projects. This assists them in making well-informed decisions that help increase production and reduce costs using responsible, sustainable practices. The server-based aspect of GIS allows sharing of important data across the globe and saves valuable time and resources. ArcGIS mobile technology provides the means to access and collect agriculturally relevant data in the field for pest management, soil treatment, and weed abatement.

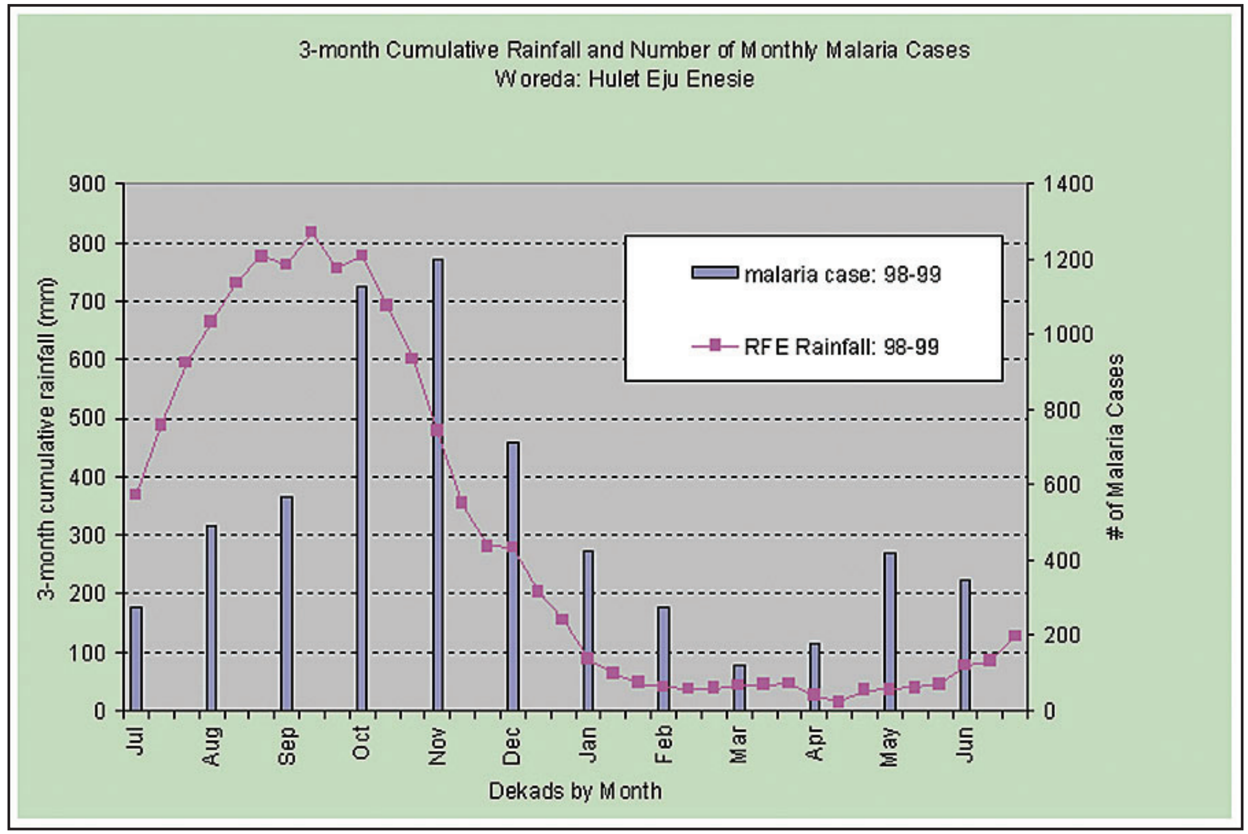
ESRI's GIS technology is being used around the world to support sustainable planning for efficient farming practices.

Sustainable development agencies use ESRI's GIS to

- Predict drought conditions.
- Monitor water resources.
- Visualize remote-sensing data.
- Model data from many sources.
- Evaluate economic and environmental impact.
- Share data and maps between agencies.
- Comply with planning and reporting regulations.
- Educate and advise communities via online services.

Bridging the African Divide with GIS

Ancient Africa, a cradle of civilization, has known kings with great perception and understanding, insightful scientists, and visionary architects. It has also known, over time, the slave trade, debilitating disease of staggering proportions, and genocide. It is a land of sharp contrasts, hanging in the balance as it does with some regions rich in natural and man-made resources while others teeter on the precipice of starvation, disease, and death.



Temporal patterns of three-month cumulative rainfall and monthly malaria cases in a district in Ethiopia during an epidemic year.

GIS technology has proven itself to be a great equalizer throughout the world in the acquisition, management, and distribution of information. In many cases, this technology can be applied to humanitarian and sustainable development efforts, which are in great need in Africa. Here are two examples of how GIS is being used.

Balancing Conservation Goals and Agricultural Needs in Cameroon

Striking a balance between conservation goals and agricultural needs is no easy task, particularly in the Republic of Cameroon, located in Central Africa.

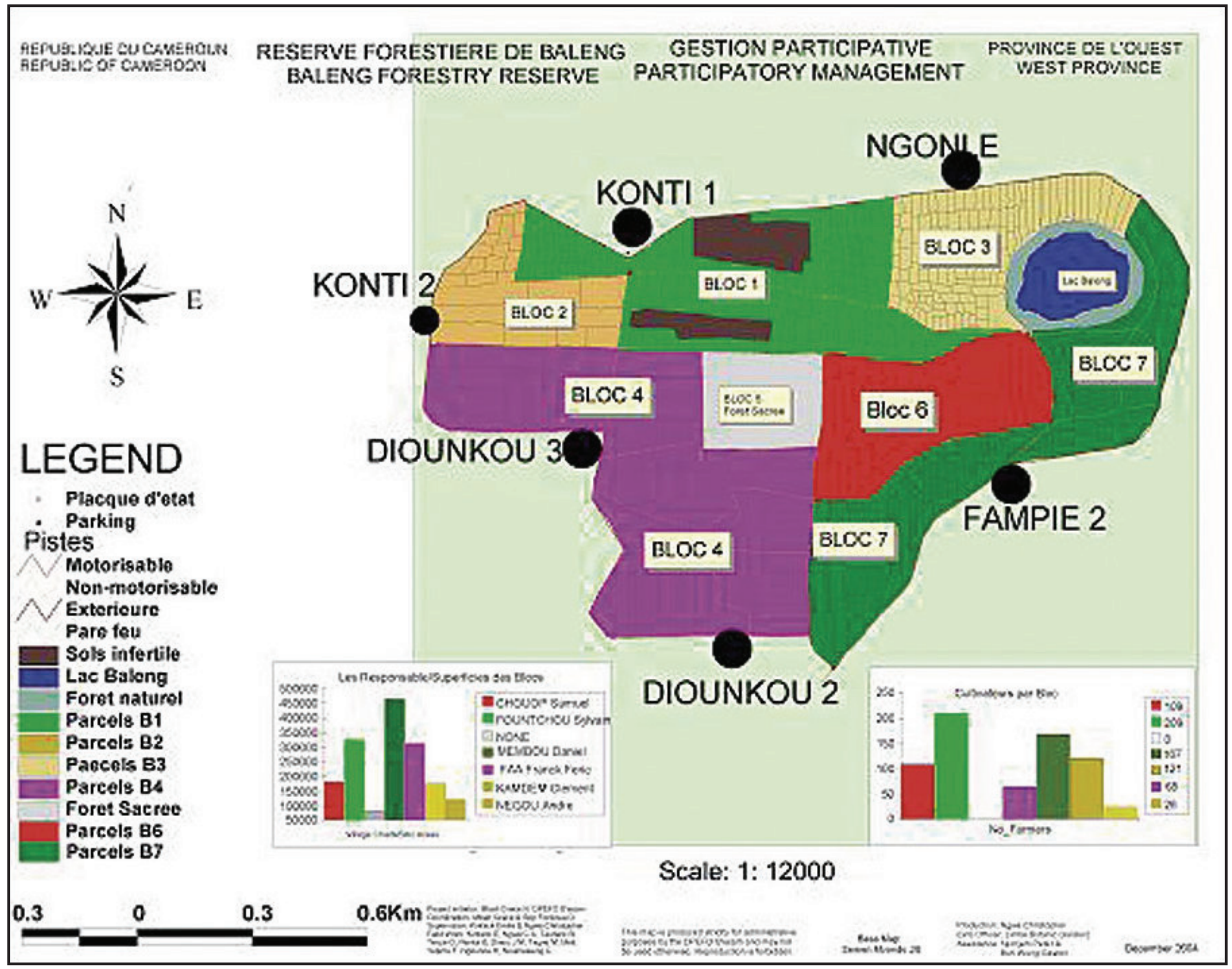
While the country has benefited economically in recent years from oil and agricultural exports, subsistence farming remains a way of life, with some of the best farmland lying in the Baleng Forestry Reserve located in the country's West Province. Water in the region is plentiful and the soil rich. These favorable conditions allow a double cropping scenario with short growth cycle crops, such as corn, beans, and vegetables, harvested twice annually.

The residents of the six villages (Diounkou 2, Diounkou 3, Fampie 2, Konti 1, Konti 2, and Ngonle) bordering the reserve began encroaching on the forest approximately 10 years ago with the compliance of village elders but without official permission from the constituted authority.

Farms are allocated by the village chiefs, and individuals with greater means and more powerful relationships can garner farmlands in different village blocks from different village chiefs, giving them control over different farms throughout the entire reserve.

Ngwa Christopher Ambe, GIS officer of the GIS/Remote Sensing Unit of Limbe Botanic Garden-Cameroon, under the coordination of the Provincial Delegate for Forestry and Wildlife for the West Province Madam Mbah Grace Nyieh, began developing methodologies for farmland management within the reserve using ArcView in 2004. As the database was updated, he became aware of this unique landownership distribution.

With the use of GIS and GPS technologies, Ambe helped develop the Participatory Management Contract Plan that established a framework allowing farmers to continue their cultivation for a fixed period of time while preserving the trees within their croplands. This was accomplished by accurately defining the borders of the Baleng Forestry Reserve, identifying those individuals and families farming within it, and documenting the trees coexisting within the cultivated areas.



GPS database used with GIS to produce thematic maps that depicted the forest reserve layout and individual farm holdings.

Describing the project, Ambe says, “Minimum farm sizes of 30 m x 30 m (900 m2) were identified within each block and used to estimate the areas of larger farm holdings by assigning code numbers. GPS waypoints were then taken for all farms and downloaded into a computer to produce a database. Field data sheets were used to collect other attribute information and manually added to the database. The database thus contained information on the number of trees per farm and per block, farm owners' identities, block codes, villages of origin, chiefs' names, and types of crops. The database was later used with ArcView to produce thematic maps that depicted the forest reserve layout and individual farm holdings. The maps educated everyone involved in the reserve. Reserve and village block management committees were then set up to sustain tree nurseries and replanting under the supervision of forestry technicians and local day and night watchmen. The signing of participatory management contracts ensures the safety and maintenance of nurseries and replanted trees and the subsequent regeneration of the destroyed reserve, while guaranteeing continuous cultivation for a transitional period of 10 years (after which all the farmers must quit the reserve), thereby halting further deforestation and ensuring food security for the villagers."

Penalties for removing trees within the reserve include both incarceration and fines ranging from $400 (U.S.) to $2,000 (U.S.), as stipulated by national laws. In addition, the value of the felled trees is calculated and added to the court fines.

Concludes Ambe, "Since our maps of the reserve are completely georeferenced, the individual farms within the reserve are all coded and the trees within the farms documented, providing us with very good information regarding the trees within the cultivated land that are the responsibility of the farmers to protect. If we discover a felled tree, we simply take its GPS point and can easily determine whether or not the tree is within the reserve, and if so, we can bring the culprit to justice."

Modeling Potential Malaria Hotspots in Ethiopia

Nearly a million deaths occur annually in sub-Saharan Africa as a result of malaria. It kills an African child every 30 seconds, and those who are fortunate enough to survive a severe episode of the disease may suffer lasting learning impairments or brain damage. In Ethiopia, more than 65 percent of the country's 70 million people are exposed to malaria, and more than five million cases of the disease are diagnosed each year.

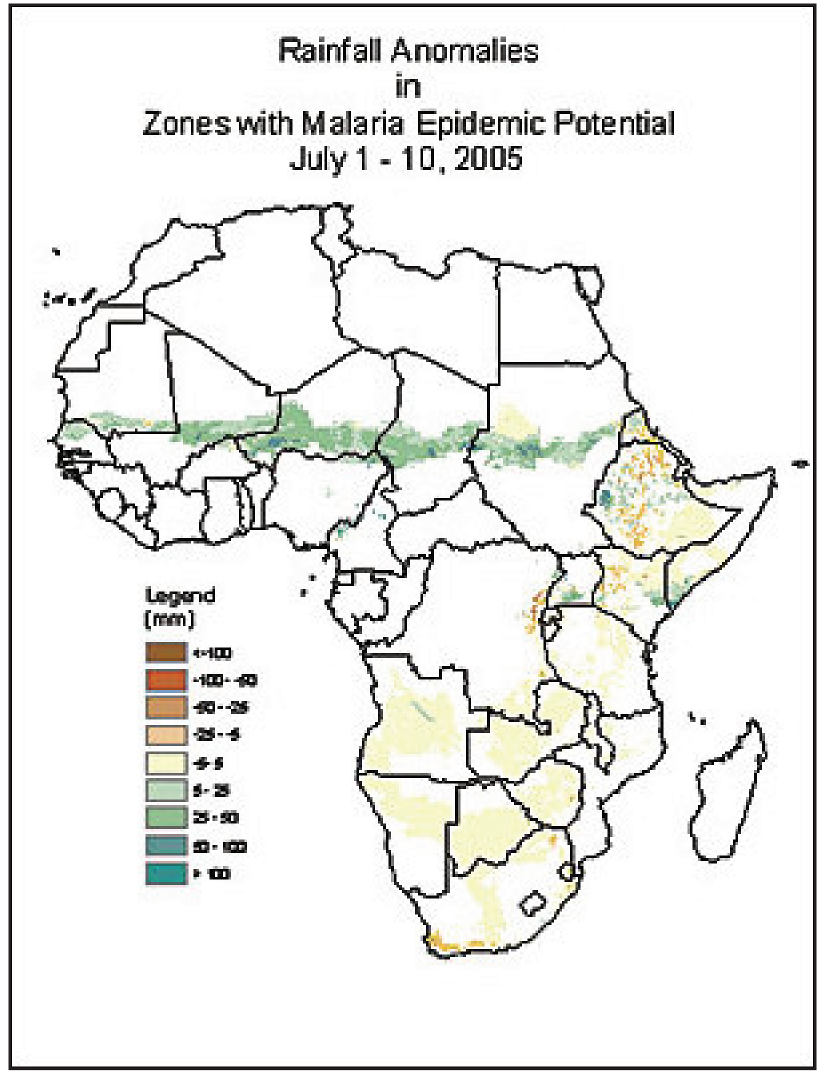
Ethiopia's Ministry of Health summarizes the impact of malaria on the country, "The socioeconomic burden resulting from malaria is immense. The high morbidity and mortality rate in the adult population significantly reduces production activities. The prevalence of malaria in many productive parts of the country prevents the movement and settlement of people in resource-rich low-lying river valleys, while the concentration of population in nonmalaria risk highland areas has resulted in a massive environmental and ecological degradation and loss of productivity that exposes a large population to repeated droughts, famine, and overall abject poverty. The increased school absenteeism during malaria epidemics significantly reduces the education of students. In addition, coping with malaria epidemics overwhelms the capacity of health services in Ethiopia and, thus, substantially increases public health expenditures."

According to Gabriel Senay, a senior scientist at the National Center for Earth Resources Observation and Science (EROS), "Malaria in Ethiopia is not only a health issue, it is also a food security and environmental issue."

To help counter this scourge, a Malaria Early Warning System is being developed for deployment throughout Africa. Several studies have been made to connect malaria epidemics and weather variables. Rainfall, temperature, humidity, and soil moisture are factors known to affect the transmission rate of malaria.

Efforts to predict malaria epidemics focus on the role weather anomalies can play in epidemic prediction. In addition to weather monitoring and seasonal climate forecasts, epidemiological, social, and environmental factors can play a role in predicting the timing and severity of malaria epidemics. Basically, certain conditions can produce a surge in numbers of both the parasite that causes the disease and the host mosquito that spreads it. The data related to the various factors that lead to the increase of both the malaria parasite and mosquito can be incorporated into a GIS to develop predictive models for malaria epidemic forecasting.

EROS uses satellite imagery in conjunction with ArcGIS Desktop software ArcView and ArcInfo to develop such models. The data is analyzed and overlaid on a topographical map to determine the likely time and location of pending malaria outbreaks.



Rainfall anomalies of July 1–10, 2005, in malaria epidemic potential zones of Africa.

“What we have determined,” comments Senay, “is that the presence of a lag time between peak malaria transmission and seasonal rainfall events is very important for forecasting malaria outbreaks using observed weather data. Once the main rainy season declines in intensity and frequency in September, the increasing average daily temperature and progressive dryness beginning in mid-September create a conducive environment for mosquito breeding in areas where water has been accumulating from the main rainy season. The lag time between the end of the main rainy season and peak malaria transmission can be explained by the inherent lag time in mosquito breeding and parasite life cycle inside the mosquito, which are dependent on air temperature and humidity.”

By highlighting potential malaria hotspots identified with GIS-based predictive modeling, affected communities can be mobilized to perform preventive or mitigating activities to help minimize the severity of the pending outbreak.

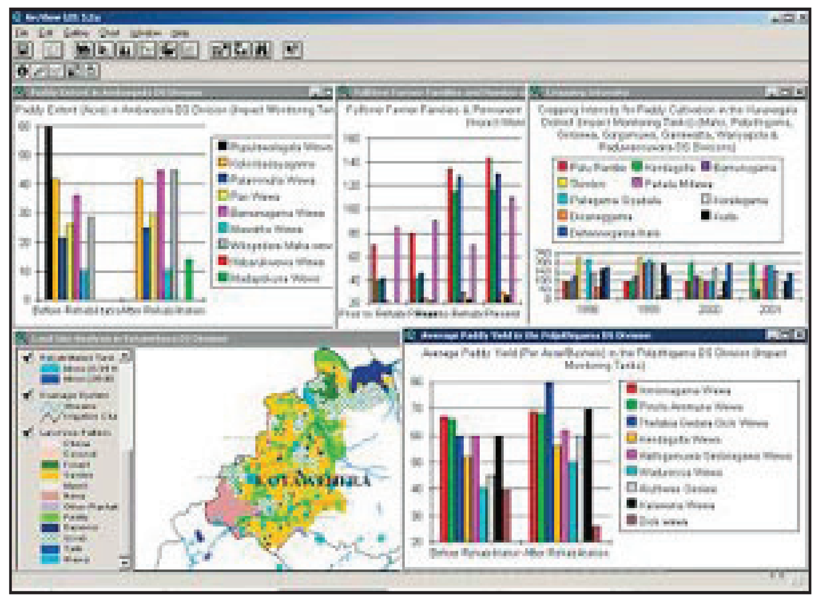
(Reprinted from the Fall 2005 issue of *ArcNews* magazine)

Sri Lanka Uses GIS for Planning and Management of Irrigation Systems

With the Assistance of the United Nations World Food Programme

In Sri Lanka, 80 percent of the poor live in rural areas. Poverty to a large extent coincides geographically with the rain-dependent dry zone, which has been subject to prolonged and recent drought. Numerous minor irrigation water reservoirs, called tanks, store seasonal rainfall for agriculture production, animal husbandry, and domestic purposes. In the past, communities have failed to maintain irrigation schemes, which has led to decreased food security.

Therefore, beginning in 2002, the Community Managed Rehabilitation of Minor Irrigation Schemes (MIS) Project was jointly implemented in 17 districts of the dry zone by the United Nations World Food Programme (WFP) and Sri Lanka's Department of Agrarian Development (DAD) of the Ministry of Agriculture.



Analysis of socioeconomic and impact of rehabilitated schemes in the Kurunegala District.

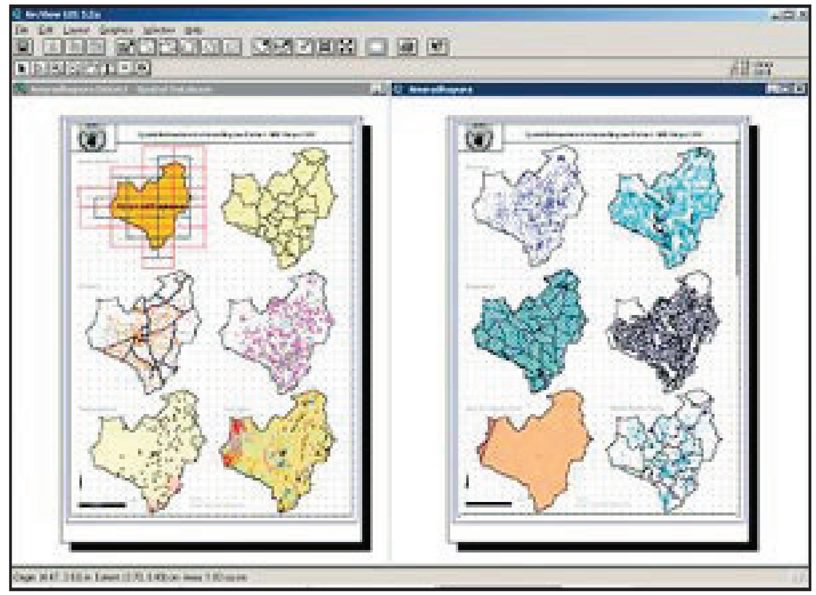
WFP-assisted development projects were approved to increase incomes and employment of the small farmers through improved irrigation and, as a consequence, increased and diversified agricultural production. DAD has implemented GIS to help select tanks that will be rehabilitated in the future and to assess the impact of rehabilitated minor irrigation systems on poor farmer families in WFP activity districts. In addition, GIS is now being utilized not only as a system to monitor the sustainability of the rehabilitation process but also to measure changes in agricultural patterns and the process's impact on the living conditions of the poor farmer families.

Through the development of these minor irrigation schemes, farmer groups acquired much-needed water as well as skills in water management and sustainable agricultural practices. DAD intends that the project will cover 660 minor irrigation schemes in eight priority districts by 2006: Anuradhapura, Kurunegala, Puttalam, Matale, Kandy, Moneragala, Badulla, and Ratnapura.

Data for GIS and the Sources of Data

DAD is the responsible government department for rehabilitation and maintenance of minor irrigation systems for the entire country. As early as 1998, DAD conducted a comprehensive tank inventory study with 76 attribute fields collected per tank regarding technical aspects, cultivation practices, catchment area characteristics, etc. System updating was then conducted annually.

In addition, 52 one-inch to one-mile topographical map sheets covering the entire study area of the MIS project (published during the period from 1977 to 1998 by the Department of Survey, Sri Lanka) needed to be converted for GIS use. ArcInfo was used for the spatial data conversion by manually digitizing topographical map sheets and then converting data into transverse projection. ArcView was an important management tool for identifying tanks for rehabilitation, monitoring tanks, and evaluating rehabilitated minor irrigation schemes as well as updating the attribute fields on each rehabilitated minor irrigation scheme. Since the topographic map sheets had not been updated after 1998, ArcPad 6 enabled project staff to extract accurate current data within a short time.



GIS database for the MIS Project.

The spatial database for each district was categorized into five sections:

- Administrative (district, divisional secretarial divisions, and agrarian service center boundaries)
- General (road network, township, and public utilities)
- Drainage (tanks, streams, irrigation channels, and main/subwatershed boundaries with cascades)
- Topographical (elevation pattern [based on 500-meter intervals] and trigonometric points)
- Other information (soil types, agro-ecological zones, urban, and census)

The identified themes were projected on Mercator projections, and each minor irrigation scheme was linked with the existing tank inventory database based on a unique minor irrigation scheme identification number.

In the process, 1,086 minor irrigation schemes that had already been rehabilitated from 1994 to 2001 were identified, demarcated, and separately classified with relevant attributes.

In addition to selecting the rehabilitated irrigation schemes, GIS is used to monitor the sustainability of the rehabilitation process. For this purpose, relevant socioeconomic and specific scheme data was collected in all WFP activity districts with the assistance of agriculture, research, and production assistants (ARPAs). ARPAs were trained to collect data for each scheme using an impact evaluation questionnaire. Impact monitoring training programs were conducted continuously in 11 sessions, and 447 minor irrigation schemes were selected for analyzing the impact on the living conditions of the poor farmer families and vast changes of agricultural patterns (cultivated land extents, harvest variations, cropping intensity, and cropping patterns).

Capacity of DAD GIS Center and Trained Staff

A significant component of the development and maintenance of any GIS is a staff that is fully aware of the power of GIS. DAD staff had been trained to collect and input primary data. In addition, technical assistants from the eight priority districts and engineers were trained to extract the required data from the system for the MIS project.

ArcInfo, ArcView, and ArcPad were demonstrated at the head office and during a series of workshops at district level. Presently, DAD is well equipped with a GTCO A0 size digitizer and a large format HP Designjet color plotter. A Leica GS5+ GPS enables DAD to identify minor irrigation schemes in conflict-affected districts in the northern and southern provinces of Sri Lanka. The next DAD/WFP project is to create a district-level GIS network in four districts (Puttalam, Anuradhapura, Kandy, and Badulla) equipped with ArcView.

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International Coffee Marketing and Certification Aided With GIS

U.S. Geological Survey EROS Data Center Responds to Needs of Coffee Producing Countries

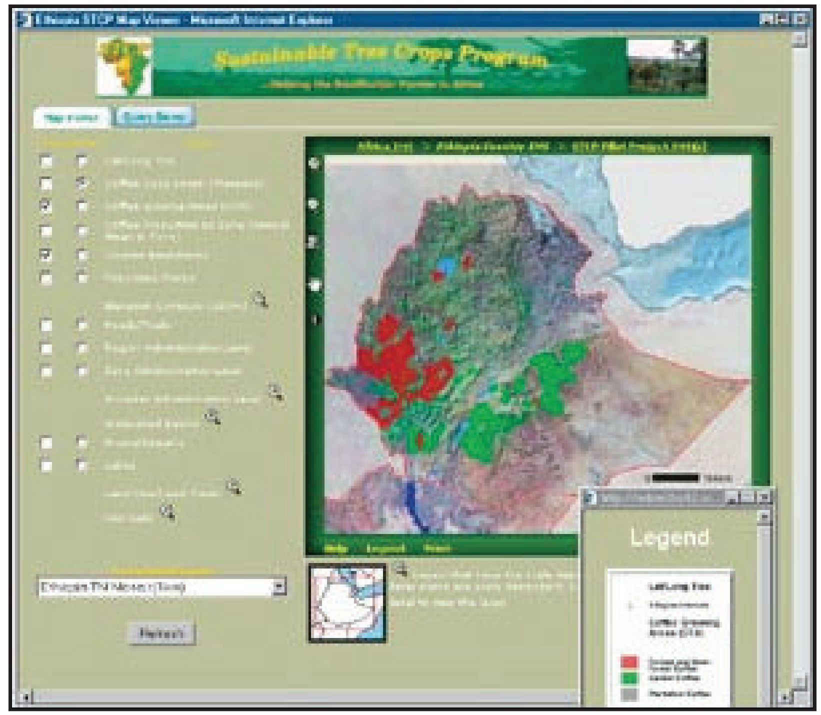
By Eric van Praag and Eric Wood, U.S. Geological Survey EROS Data Center

Coffee is one of the most important commodities traded internationally. Its commerce impacts the lives of millions of coffee workers around the world, and many countries depend on this trade as their main source of foreign income. The recent decline in coffee prices, now at historic low levels, has created havoc in the economies of these countries. In El Salvador alone, a small coffee producing country of 5.8 million inhabitants, 80,000 jobs were lost in the coffee sector in 2002. The blow has been felt the most by the small farmers in Latin America, the Caribbean, and Africa.

The applications described below identify the role that readily accessible and georeferenced information can play in supporting the development of specialty coffee markets to secure premium market value. The term specialty coffee refers to several categories of coffee, such as single-source, gourmet, premium, organic, shade-grown, bird-friendly, and fair trade, which command better prices than the traditional coffee brands found on supermarket shelves.

An increased trade in specialty coffee benefits both coffee producers and the environment. Specialty coffee production is often done in a sustainable way that helps maintain healthy forests and ecosystems. In El Salvador, for example, approximately 60 percent of forest cover is associated with shade-grown coffee. In Mexico, Smithsonian biologists found that coffee plantations with protective tree cover support more than 150 species of birds, a greater number than is found in other agricultural habitats and exceeded only in undisturbed tropical forests.

When compared with the traditional coffee market, the specialty coffee market requires better information as well as increased transparency in transactions. Information is required on several aspects of coffee production and marketing including exact location of coffee farms, cooperatives and mills, socioeconomic conditions, environmental and climatic data, production and milling processes, materials and inputs used in coffee production, and general marketing information.



Coffee growing regions are draped over a satellite image mosaic of Ethiopia (source: Landsat ETM+ data from the EROS Data Center). Consumers and marketers can access production data collected as part of a pilot project.

Projects in Africa and Latin America

The U.S. Geological Survey (USGS) Earth Resources Observation Satellite (EROS) Data Center (EDC), with funding provided by the United States Agency for International Development (USAID), is responding to the need of coffee producing countries in Latin America and Africa to develop and exploit the specialty coffee market by assisting them in the development of ArcIMS software-based marketing and certification systems. Applications have been implemented in the Dominican Republic, Peru, and Ethiopia as well as in several Central American and African countries.

Leonidas Batista, head of the Dominican Republic Coffee Board (Codocafe), sees this type of application as the way forward, “The new specialty coffee market demands timely and accurate information, the provision of which can be greatly facilitated by the use of information tools and data sets that can be integrated on the Web by Internet Map Servers.”

As part of a cooperative project in the Dominican Republic, Codocafe, the Dominican Agricultural Research Institute, coffee cooperatives, USAID, and EDC have teamed to implement certification and marketing tools based on documented practices, appropriate conservation, and biodiversity protection; robust and maintained databases; and tools provided by ArcGIS and ArcIMS. Of the 45,000 coffee holdings in this country, the ArcIMS application developed by the project contains detailed data and georeferenced positions of more than 2,000 farms already producing specialty coffee or with the potential to do so.

Individual coffee farms are precisely mapped with handheld GPS devices, and a variety of data is collected for each farm, ranging from geographic and climatic conditions, socioeconomic data, and production information to harvesting periods, certification issues, and types of protective trees. The data is integrated into databases, converted to digital maps (ArcView shapefiles) for online visualization, and displayed together with other existing and newly generated spatial data sets such as protected areas, forest cover, shaded relief, topography, hydrography, cities and towns, and river basins. Other specialty coffee online mapping projects initiated by EDC in Peru and Ethiopia follow a similar approach.

Who Benefits From These Applications?

Benefactors of these applications are numerous. Take, for example, coffee traders in the United States or Europe. With the use of a simple Internet browser, they can consult the Dominican Republic ArcIMS application, easily choose to visualize those farms located in the central mountain range higher than 1,000 meters in elevation and producing certified organic coffee, and contact the cooperatives producing the coffee they are interested in to obtain samples. Government officials, scientists, and other users might have different needs for information such as which coffee farms are located in areas without protective forest cover or at altitudes unsuitable for coffee production or which farms have received subsidies or have been affected by specific coffee pests. Searches are made possible by accessing a powerful query engine developed by EDC specialists using ArcIMS and Active Server Pages (ASP). Search results are displayed in both map and tabular format for easy consulting and printing.

John Becker, USAID agricultural policy advisor, views these ArcIMS applications as part of a bigger agricultural verification effort, “To certify you must be able to verify, and the collection, transfer, and storage of digital evidence provide a cost-effective method of verification. The combined use of the Internet with GIS and GPS to help certify specialty coffee represents just the beginning of the new, expanding field of agroecological system verification that is being driven by market-based and regulatory requirements for traceability and identity preservation in globally traded agricultural products.”

These technologies, combined with the use of remotely sensed data, also offer the potential to monitor several environmental indicators such as the impact of coffee production on adjacent forests, the maintenance of forest corridors among coffee producing areas, the encroachment of coffee farms in protected areas, shade tree density, and volume of sequestered carbon, among others.

(Reprinted from the Winter 2003/2004 issue of *ArcNews* magazine)

Spreading Data Improves Crop Yield

New Zealand Fertilizer Application System Uses GIS/GPS

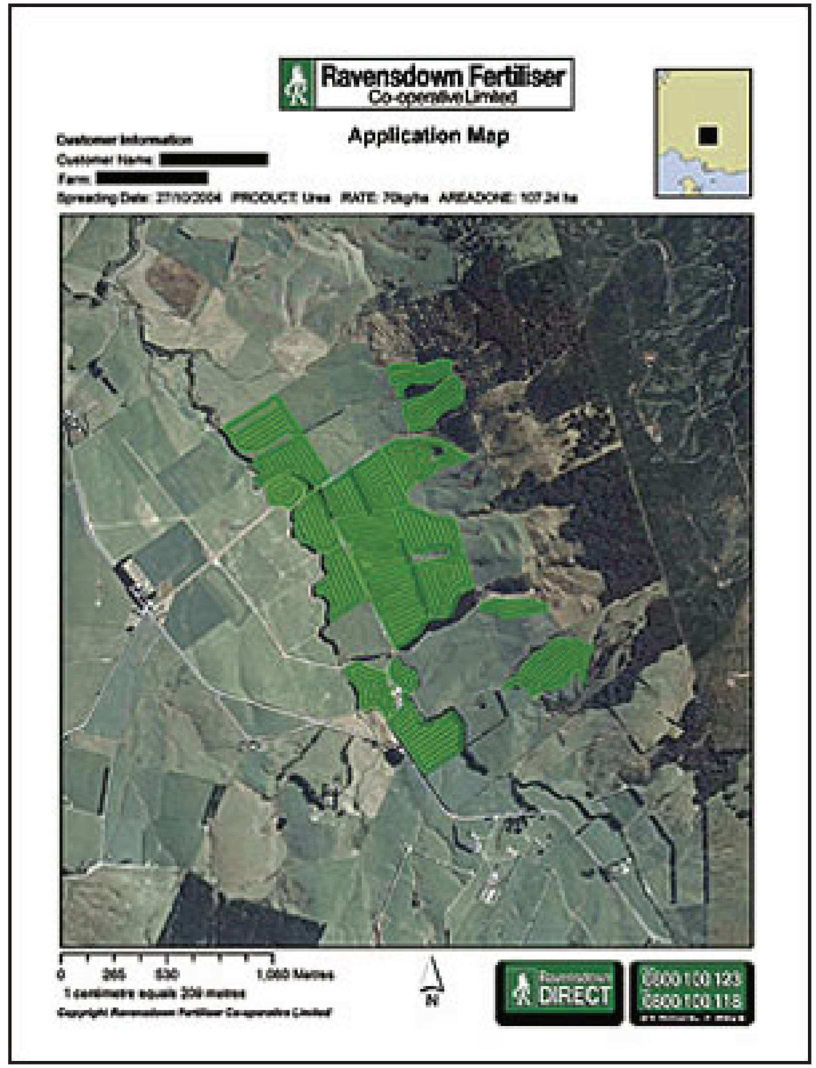
Technology enables farmers to become more discerning about crop management. Modern precision farming techniques incorporate geospatial technologies to help farmers increase economic yield. Using data from satellites and aircraft, precision farmers can pinpoint problems with drainage, insects, and weeds. They learn where fertilizers are needed and where they are not. Technology has made fertilizer application a precise science. With these methods, farmers have greater control of crop yields before they plant a seed.

In past generations, farmers tended to spread fertilizer evenly over the entire field. Now spreading methods can be more exact by type, quantity, and location of application. Decking the cockpit of the spray rig with computerized controllers and GPS navigation systems is an approach to farming that is both friendly to the environment and profitable to the farmer.

Ravensdown, New Zealand's largest manufacturer and distributor of fertilizers, is using geospatial technology for applying fertilizers that helps New Zealand farmers save money and also protects the environment. By using GIS and GPS to direct application of fertilizers, farmers reduce the amount of potentially harmful runoff of fertilizers into streams and waterways. At the same time, they are reducing their total expenditures on fertilizers by up to 10 percent per annum.

Ravensdown worked with ESRI's New Zealand distributor Eagle Technology Group to design the solution that is built on ArcGIS Server software. The system accurately records where and how much fertilizer has been applied to a certain area. This information is merged with digital orthophotos and the farm's relational databases to create a vivid picture of the farm's overall soil sustainability.

A key concept in New Zealand agriculture is the nutrient budget, which measures all of a farm's nutrient inputs and outputs, including fertilizers, feeds, and farm produce. Ravensdown's new GIS-based system helps farmers optimize their nutrient budget and ensure that their soils receive just the right amount of fertilizers for high crop yield.



Once the data has been uploaded and processed, Ravensdown field staff members can log on to the system from a remote location via the Internet. They can call up a customer's farm, see the results of earlier soil tests, see what types of fertilizers have been applied, then make recommendations about which types of fertilizers are appropriate.

Ravensdown and Eagle collaborated closely during the implementation process. The system integrated GIS, GPS, wireless transmission, and Internet and intranet technologies, as well as data from various sources. Ravensdown's GIS architecture includes ArcGIS Server, ArcSDE, ArcIMS, and ArcGIS Explorer. Once the raw spatial and attribute data is captured from GPS transceivers on the spreader trucks, it is transmitted wirelessly to Ravensdown's facility where it is loaded into the GIS and processed in near real time.

Ravensdown had already equipped a number of its fertilizer application trucks with GPS-controlled guidance systems and spreaders that captured location, fertilizer type, and spreading data. The GIS creates a map-based display that shows fertilizer application data as a series of color-coded "snail trails" that are overlaid on the map, giving a very good representation of the process.

Ravensdown had already equipped a number of its fertilizer application trucks with GPS-controlled guidance systems and spreaders that captured location, fertilizer type, and spreading data.

An additional benefit is that the system can be used as evidence of "proof of placement" to demonstrate that the fertilizer has been spread in a manner consistent with best environmental practices.

Once the data has been uploaded and processed, Ravensdown field staff members can log on to the system from a remote location via the Internet. They can call up a customer's farm, see the results of earlier soil tests, see what types of fertilizers have been applied, and then make recommendations about which types of fertilizers are appropriate. The company's call center representatives have access to the same information and can immediately access this information from its customer relationship management (CRM) system, again in map format. This gives service representatives all the information they need to resolve most phone queries from clients. Maps can be delivered in printed format, e-mailed, or faxed to clients.

Eagle used the development capabilities available in ArcGIS Server to embed the map interface in Ravensdown's CRM system. Ravensdown wanted seamless access to the spatial and attribute data, so Eagle Technology developers used the .NET framework to build an interactive map viewer that call center staff can access with a click of the mouse. Staff members can query the database, manipulate the display, and print or fax hard-copy maps. This same model will be used to expand the system to Internet-based users in the future.

Ravensdown has had an ongoing program of using geospatial technology to improve services to clients. Its Digital Farm Mapping service combines orthophotos from Terralink and agricultural farm management software from AgResearch to support its clients. The fertilizer-spreading application complements this mapping service and gives the company more capabilities to expand in the future.

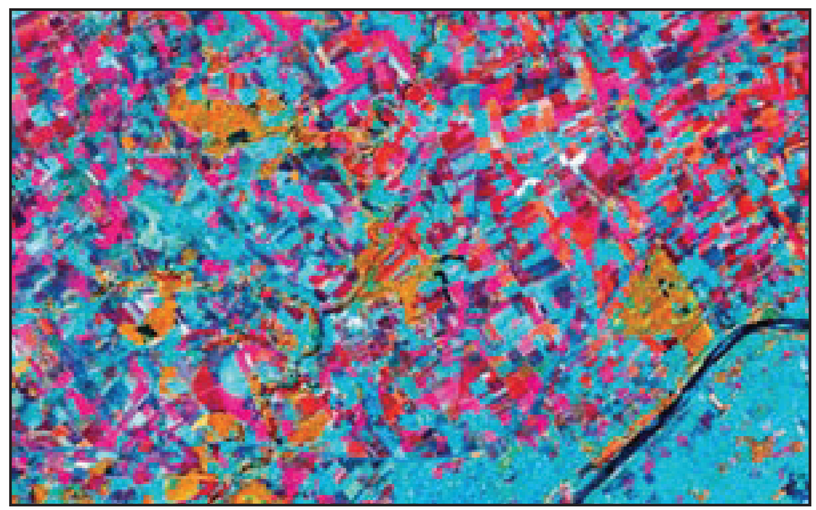
Ravensdown is planning to build on this foundation. "Eventually, we want to enable our clients to log in to an enhanced system from their own Internet browsers," says Mark McAtamney, CIO at Ravensdown. "We also want to incorporate GIS into our quoting system to calculate the road distance between our depots and the fields to be fertilized. The distance is a significant component of the cost to our clients. We are just scratching the surface when it comes to developing further applications for the system."

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

U.S. Department of Agriculture Produces Objective and Accurate Global Assessments With GIS

The Production Estimates and Crop Assessment Division (PECAD) of the U.S. Department of Agriculture (USDA) Foreign Agricultural Service (FAS) is responsible for global crop condition assessments and estimates of area, yield, and production for grains, oilseeds, and cotton. The primary mission of PECAD is to produce the most objective and accurate assessment of the global agricultural production outlook and the conditions affecting food security in the world. Regional analysts use GIS to collect market intelligence and forecast reliable global production numbers for the grain, oilseed, and cotton crops.

The GIS utilizes several different satellite data sources—climate data, crop models, and data extraction routines for yield and area estimates—to determine production (production = yield x area). FAS has a global network of attachés who provide on-the-ground reports of observed crop and contextual information. Also, FAS regional analysts travel extensively in the countries they cover to more fully develop the context and constraints within which their assessments are made.

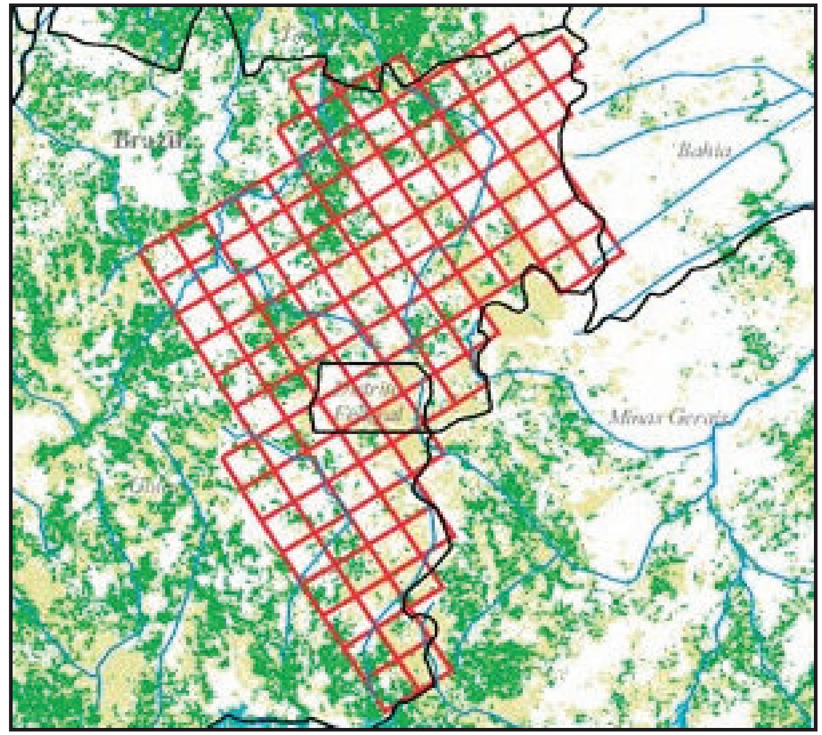


False color Landsat TM image in Central France taken on May 29, 2003. Red colors indicate vegetation.

Other contextual information, such as official government reports and trade and news sources, plays a significant role in interpreting how these factors will affect price and policies and other econometric analyses. PECAD's final production estimate, produced by the 10th day of each month and cleared by the World Agricultural Outlook Board, is based on an all source convergence of evidence methodology. The final production estimates are used in a variety of ways including

- Official USDA statistics
- Principal federal economic indicators
- Crop conditions and early warning alerts
- Agricultural monitoring and food security
- Foreign aid assessments for food import needs
- Disaster monitoring and relief efforts related to food aid
- Commercial market trends and analysis
- Trade policy and exporter assistance

PECAD relies on remote sensing data from satellite sensors as an important source of data for its GIS reports. Selected data sets provide daily, weekly, and targeted coverage with resolutions ranging from one kilometer to less than one meter. The data is stored on a terabyte server accessible to each analyst's workstation. Because the USDA standardized with ESRI GIS in 2001, TIFF and compressed MrSID images are used operationally with ArcGIS Desktop (ArcInfo, ArcView, and ArcEditor).



Polygons outlined in red are selected AFWA grid cells for crop producing region in Brazil.

The Crop Condition Data Retrieval and Evaluation (CADRE) database is the main decision support tool used in the GIS by PECAD analysts. CADRE is a global grid-based, geospatial database that stores daily, monthly, and decadal (10-day) data. The sources for this data are the Air Force Weather Agency (AFWA) of the U.S. Air Force and the World Meteorological Organization. PECAD takes this source data and models precipitation, temperature, soil moisture, and crop stages. To measure vegetative vigor, PECAD calculates vegetation index numbers (VINs) from satellite-derived data. The data is imported into one-eighth degree mesh grid cells and can be categorized in the following three manners:

- *Time series data sets*—Daily agrometeorological data derived from station and satellite data includes precipitation, minimum and maximum temperatures, snow depth, solar and long wave radiation, and potential and actual evapotranspiration. Daily and decadal VINs were derived from local area coverage (approximately 1.1 km pixels) and global area coverage (approximately 8 km pixels from the National Oceanic and Atmospheric Administration's advanced very high-resolution radiometer [AVHRR] satellite series).

- *Normal baseline data sets*—Normal precipitation, temperature, potential evaporation, and elevation values; soil water holding capacity based on the United Nations Food and Agriculture Organization's Digital Soil Map of the World at 1:5,000,000 scale; and decadal VIN normals or averages for the global area coverage data set.
- *Crop information and models*—Crop type and average start of season, average yield and area planted, percent crop production within a country, two-layer soil moisture algorithm, crop calendars based on growing degree days, crop stress or alarm models for corn and wheat based on soil moisture and temperature thresholds, crop water production functions to estimate relative yield reductions (yield reduction models), and crop stage models.

ArcGIS is essential in managing the geospatial data from CADRE and the various other data sources used at PECAD. Much of the baseline data sets are stored as shapefiles on PECAD servers. The ArcMap application of ArcInfo is used to geographically combine the varied data sets in a visual assessment to determine a convergence of evidence analysis. Commodity production is then estimated from the yield and area parameterization. Although analysts have a disparate array of region specific data sources and crop growth models at their disposal, PECAD's GIS allows analysts to spend less time on repetitive analysis tasks and more time on utilizing all available data for the monthly crop production assessments. ArcIMS is being used by PECAD to automate these tasks and make data model results and ancillary data more accessible.

The Crop Explorer Web application (www.pecad.fas.usda.gov/cropexplorer) features near real-time global crop condition information based on the satellite imagery and weather data processed by PECAD. The Web mapping application uses ColdFusion, Java, ArcIMS, SQL Server, and ArcSDE to manage and store the geospatial data. ArcSDE relationships are set up between PECAD "regions" and the various feature classes used by the maps (e.g., rivers, administrative boundaries). The Crop Explorer ArcIMS MapService is built using these same ArcSDE features. During a map generation request, the grid cell layer feature class is joined to the appropriate attribute data such as precipitation, soil moisture, or temperature.

Thematic maps of major crop growing regions depict vegetative vigor, precipitation, temperature, and soil moisture. Time series charts depict growing season data for specific agrometeorological zones. Regional crop calendars and crop area maps are also available for selected regions. U.S. producers, traders, researchers, and the public can use Crop Explorer to visualize this information with a Web browser.

Regional droughts or excessively wet conditions can be easily identified by the amount of ground surface greenness as depicted by the Normalized Difference Vegetation Index, a measure of vegetative vigor derived from AVHRR satellite imagery. In addition, daily satellite image composites originating from the National Aeronautics and Space Administration's MODIS Rapid Response System are now directly linked to selected agricultural regions within Crop Explorer at www.pecad.fas.usda.gov/cropexplorer.

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Rangeland Health Data Collection and Analysis Improved with Mobile GIS

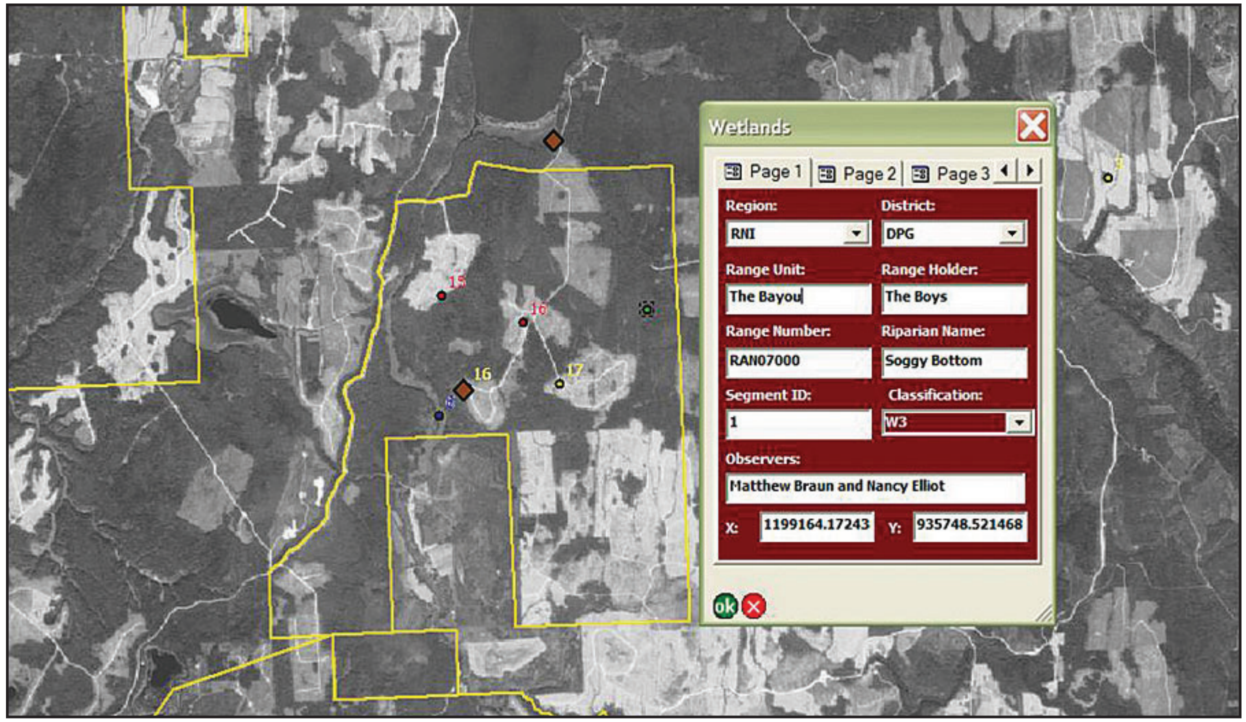
By M. D. Braun, N. Elliot, and A. Pantel, Range Branch, Ministry of Forests and Range, British Columbia

Highlights

- ArcPad allows for informed discussions with range tenure holders in a time-efficient manner.
- The operator can carry additional electronic information to calculate rangeland carrying capacity.
- Summary analysis of range health is easily created.

Rangelands in British Columbia (B.C.) are natural landscapes composed of dense coniferous forests, open coniferous forests maintained by fires, dry valley bottoms with bunch grasses, and deciduous forests with mixed prairie and alpine environments. Ranchers and guide/outfitters are allocated use permits (tenures) to graze cattle, horses, sheep, and goats on 11 million hectares of public (Crown) rangelands for four to six months per year. Ranchers interact with other rangeland users, including forestry, recreation, and oil and gas.

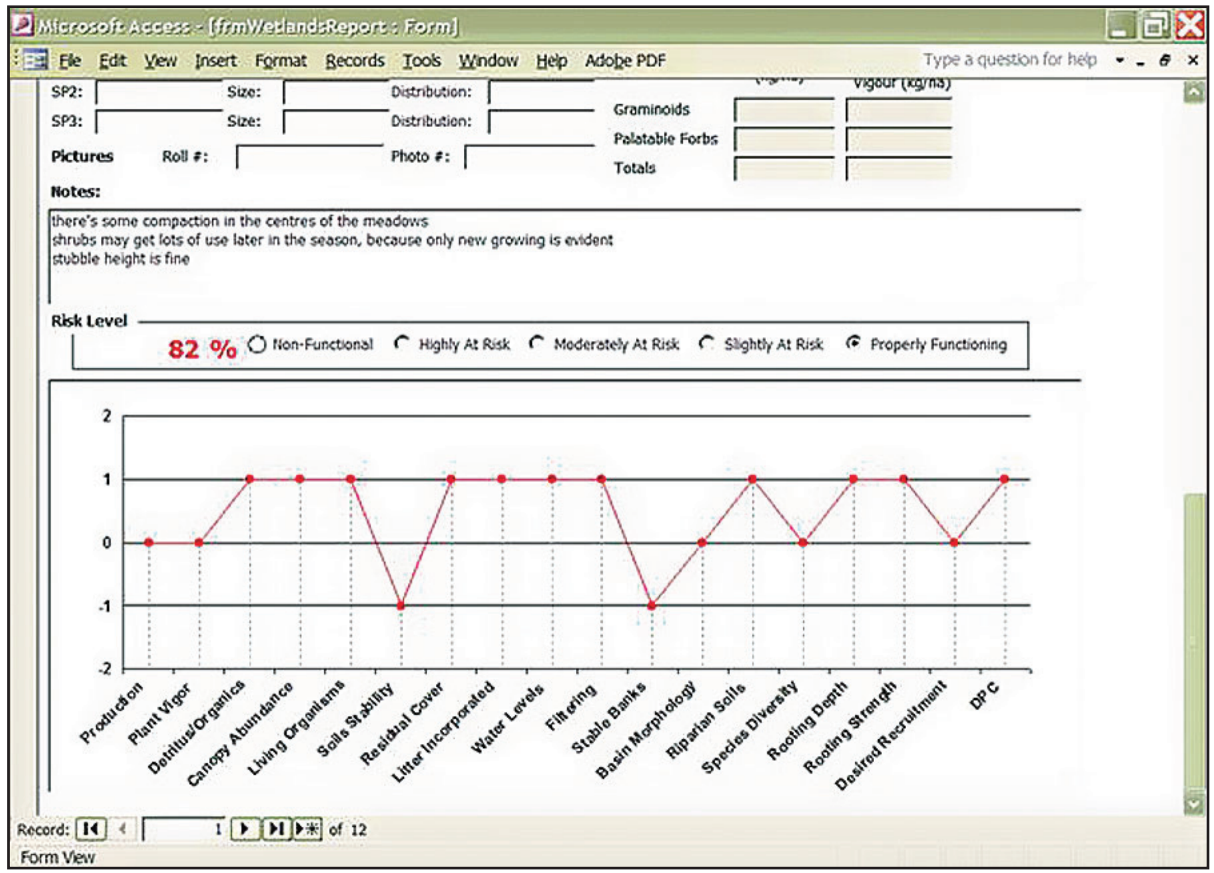
The evaluation of the impact of range practices on the quality and quantity of livestock grazing is a top-ranked priority under the B.C. Forests and Range Practices Act (FRPA). Multiple use of the diverse and large landscape necessitates systematic organization and collection of ecosystem health spatial data to facilitate monitoring by the Range Branch, Ministry of Forests and Range (MFR), British Columbia, field staff (agrologists). Reliable access to palatable plants on Crown lands supports the beef and guide/outfitters industries in this province. The monitoring and tracking of rangeland health with a handheld computer linked to a GPS enhances field data collection and analysis by agrologists.



Range health information is collected using ArcPad and digital forms. The data assists resource managers in ensuring that Crown lands provide palatable forage.

In the past, range staff collected field data with paper forms. A field day required a large paper map for navigation, clipboards, and water-resistant paper forms to record observations. Staff carried a separate GPS unit to collect spatial data and had to transfer the data to a paper form. Each day spent in the field required three additional days to analyze data and generate reports. Field observations from one week generated a box full of forms, which in turn required nearly a month to analyze and summarize.

Range staff adoption of digital technologies has notably reduced the time taken to collect data, complete analysis, and write reports. Field data collection involves recording how extensive grazing is; measuring bare soil, plant vigor, and community structure; identifying the location of range improvements; detailing the extent of weeds; determining how many animals a particular pasture will support; navigating in the field; linking digital pictures with the appropriate inspection form; and recording additional written and audio notes. Range staff report that the conversion to electronic data collection reduces analysis and summary time by at least 75 percent. Unanticipated benefits of the new technology include improved navigation and a visual summary of the extent of a monitoring regime, both of which improve the cost-effectiveness of subsequent field trips. Adopting this new technology is an important step in improving the understanding of rangeland health at a provincial level and provides data at a finer scale than in available digital layers.



Summary analysis from field data indicates the degree of risk to range health.

The staff's model of electronic data collection requires a personal digital assistant (PDA), GPS, and ArcPad mapping software to support data collection. B.C. government agencies are established users of ESRI's GIS software. Users navigate, orient themselves, and collect data by referencing base layers downloaded from a central data repository (the B.C. government's Land and Resource Data Warehouse) and displayed on their PDAs. Available information includes five-meter resolution satellite imagery; contour lines; a vegetation layer; and a blended biological, geological, and climatic layer. Data recorded in the field is output in the form of shapefiles and thus is directly compatible with the ArcGIS Desktop (ArcView, ArcEditor, and ArcInfo) software used by the MFR geomatics specialists. HP iPAQs have been used as primary PDAs by the Range Branch for more than two years because they are inexpensive and lightweight, have a clear screen, and provide a suitable processor speed for required tasks.

Effective electronic data collection requires an operator with knowledge of the ecosystem, PDA and GPS functions, and appropriate protective cases. A compact flash or secure digital memory card of at least one gigabyte is necessary to store base imagery, shapefiles, and inspection forms. Operators may find a telescopic pole useful to elevate the GPS. Users can increase field time by carrying a spare battery or mobile battery or charging the PDA and GPS in the truck between inspections. Operating time with an extended battery is six to seven hours. Most basic PDAs will have the necessary processing speed and radio receiver to operate the ArcPad software and link with a GPS. Total cost for equipment and software is between $1,500 and $2,500 per unit.

The processing power of the PDA allows the operator to carry additional electronic information from each rancher or a spreadsheet to calculate rangeland carrying capacity and thereby enables field staff to conduct partial analysis while in the field. This process supports decision making and allows for informed discussions with range tenure holders in a time-efficient manner.

Collecting data with a handheld computer allows for consistent collection of information in the form of a permanent legible electronic file that is easy to store and sort. The Rangeland Health Forms were created in partnership with Coastal Resource Mapping (CRM) Limited (Nanaimo, British Columbia). CRM generated electronic forms using ArcPad Application Builder, and data is stored in a Microsoft Access database. Summary analysis of range health is easily created through functions built into Access.

Range staff have created a guide to system operation because users are located in different areas of the province. The guide addresses topics including using ArcPad with electronic forms, acquiring and using underlying spatial data, and addressing PDA challenges. New users are most successful when they recognize the benefits of the technology and are eager to adopt it. For example, range officer Karen Tabe says that “using the technology boosts my navigation abilities, making me feel more confident when spending time in the field.”

B.C. Forest Service agrologist Rob Dinwitty completes a rangeland health inspection form using mobile GIS and a handheld computer in the middle of a sedge meadow in B.C.’s Okanagan.

In the future, range staff will be required to perform more mapping work with faster PDAs capable of performing more tasks and processing higher-resolution imagery. Plans to refine the approach include implementing Microsoft SQL Server. This will enable range data to be uploaded over the Web from various forest districts to the Range Branch’s centralized server. Field staff will maintain editing ownership over the data they collect, but central access will enable branch-level staff to view the data to conduct trend analysis at provincial-level scale, communicate problem areas to specialists, identify potential areas for restoration work, and locate areas for site exclosure monitoring.

In addition, communication of the specific location and spread of invasive plants can occur more quickly. Parsing out data from SQL Server into XML will enable upload of range health data into B.C.'s Forest and Range Evaluation Program (FREP) database. The flexibility of changing technology ensures that the Range Branch can provide FREP with monitoring data required under FRPA, as well as empower range staff to collect and analyze other significant information.

About the Authors

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