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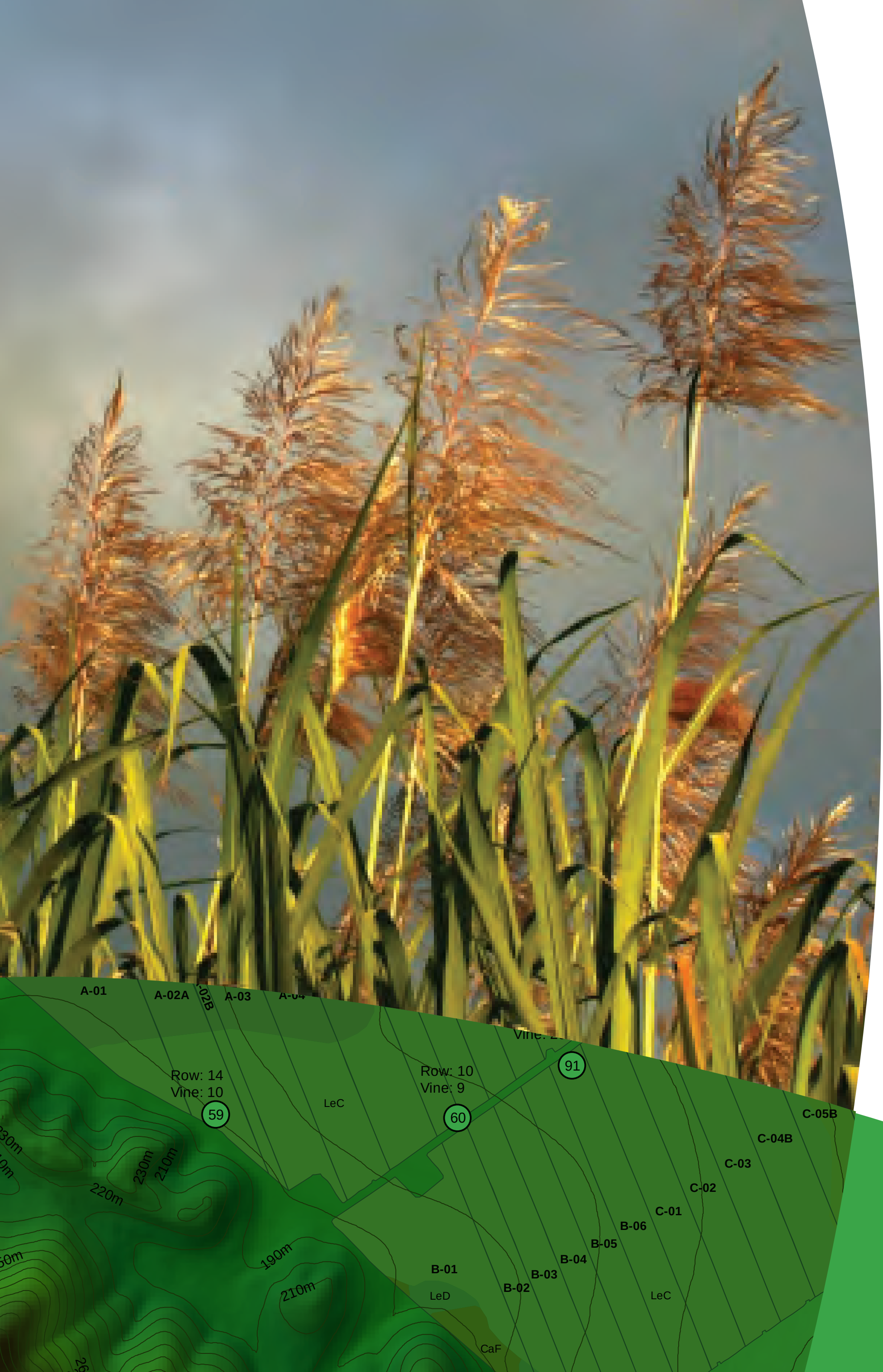

Farming the Future

GIS for Agriculture, Vol 2

cover photography courtesy of Derek Tickner

esri

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Introduction

Geographic information system (GIS) technology is used throughout the agricultural industry to manage resources, increase yields, reduce input costs, predict outcomes, improve business practices, and more.

The capability of GIS to visualize agricultural environments and workflows has proved to be very beneficial to those involved in farming. The powerful analytical capabilities of the technology is used to examine farm conditions and measure and monitor the effects of farm management practices including crop yield estimates, soil amendment analyses, and erosion identification and remediation. GIS can also be used to reduce farm input costs such as fertilizer, fuel, seed, labor, and transportation. In addition, farm managers use GIS to submit government program applications, simplifying what used to be time-consuming multistep processes.

From collecting data in the field with mobile GIS to the analysis of remote-sensing data at the farm manager's office, GIS is playing an increasing role in agriculture production throughout the world by helping farmers expand production, reduce costs, and manage their land more efficiently.

Insuring America's Farmland

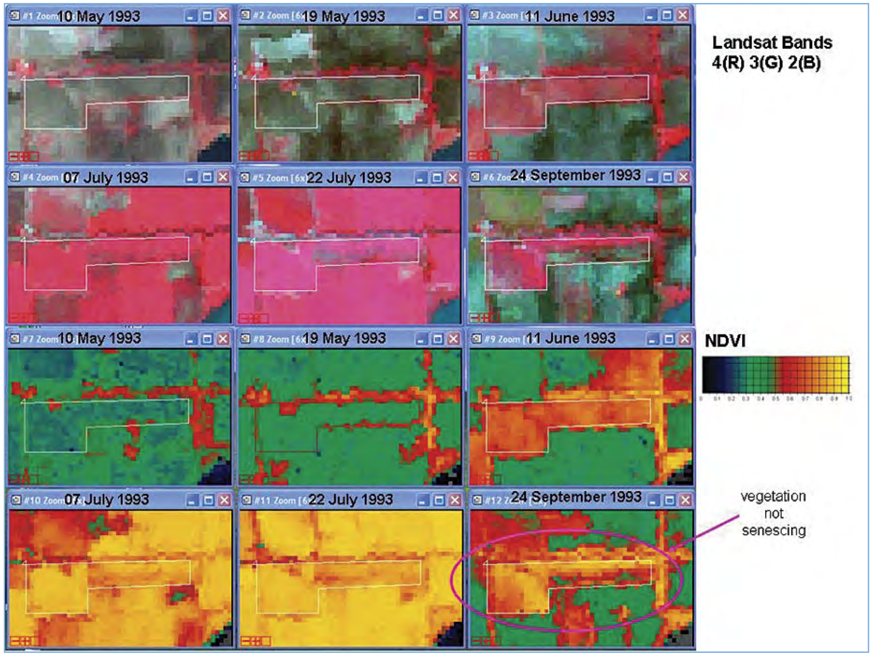
The USDA's Risk Management Agency Uses Actuarial Maps for More Equitable Premium Pricing

By Karen Richardson, Esri Writer

The United States Department of Agriculture's (USDA) Risk Management Agency (RMA), based in Washington, D.C., helps food producers manage their business risks through effective market-based risk management solutions. As part of this mission, RMA manages the Federal Crop Insurance Corporation (FCIC) to provide American farmers and ranchers with crop insurance. RMA develops and approves the premium rate, administers premium and expense subsidies, approves and supports products, and reinsures the private-sector insurance providers through the Standard Reinsurance Agreement. In crop year 2009, RMA managed nearly $80 billion worth of potential liability.

FCIC relies on actuarial maps for crop insurance to designate different areas within a county that have varying amounts of risk due to factors such as flooding or highly erodible soil based on type. These maps are used by 16 private-sector insurance companies that sell and service FCIC policies. While RMA has been using hard-copy actuarial maps for decades, it had no way to validate whether an agent or insurance company was reporting accurate claims or the claims reported were in the correct areas.

Inaccurate reporting skews the adjustment of the risk rate for producers and can create unnaturally high premiums in areas



The United States Department of Agriculture Risk Management Agency (RMA) uses forensic remote sensing to examine the growing conditions, crop health, and vigor within fields.

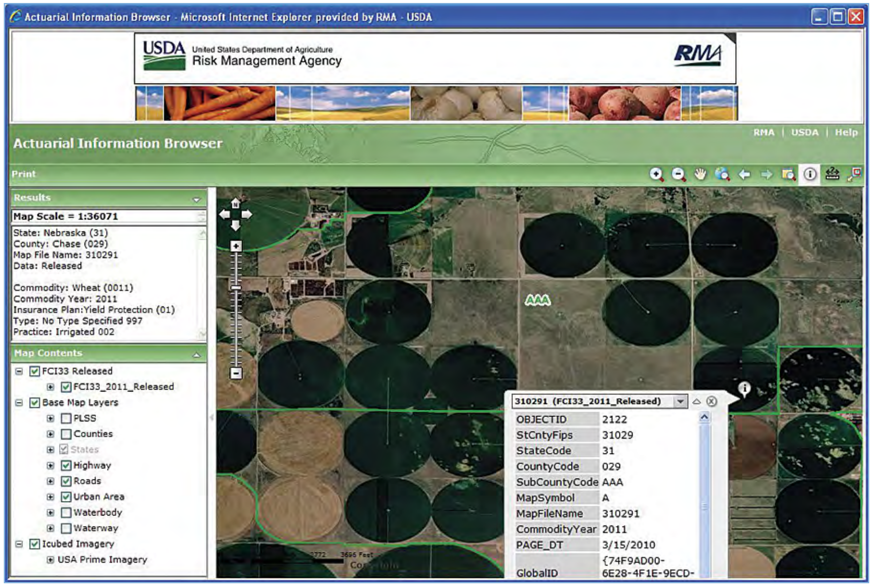
where it is not necessary. Because of this, RMA incorporated GIS to manage the information and analyze the program. Using GIS has helped RMA save $20 million a year and lower premiums for regular rated land, which in turn reduces the government subsidy on insurance across all acreage.

Saving Money and Time

Since most federal agencies are standardized on Esri software and data formats, RMA chose to incorporate Esri software in the early 2000s to begin the FCI-33 Actuarial Map Digitizing Project to convert hard-copy maps, using aerial photos and USDA Common Land Unit data, into GIS. This process took several years, and at the end, RMA's 10 regional offices digitized more than 1,500 maps into shapefile format.

Managing such a large number of digital maps was difficult, prompting USDA to upgrade to ArcGIS when it was released and use a personal geodatabase to manage the digital files. The geodatabase allowed it to aggregate the maps into 10 more manageable feature classes instead of the 1,500 stand-alone maps. In 2008, RMA upgraded to ArcGIS Server, which allows it to more easily share the data throughout its regional offices using a central server without keeping copies of maps on regional office computers.

RMA uses the digital actuarial maps to cross-check and approve maps generated by the regional offices. "The ability to validate these automatically instead of by hand has saved us so much time," says Greg Oetting, risk management specialist, USDA-RMA, Topeka Regional Office.



The RMA Actuarial Information Browser map viewer is used by farmers, crop insurance agents, approved insurance providers, and RMA to view insurance offers at a subcounty level.

The actuarial maps for 2010 and previous years are published as PDF files on the Internet for the insurance companies to view. In 2011, RMA rolled out an interactive map viewer that is hosted publicly. Insurance companies have access to the data and can host it internally. "This will be a real time-saver to RMA," says Oetting. "Creating the map viewer means we don't have to spend time and man-hours building out and proofing 1,500 individual PDFs."

Analyzing the Crop Insurance Program

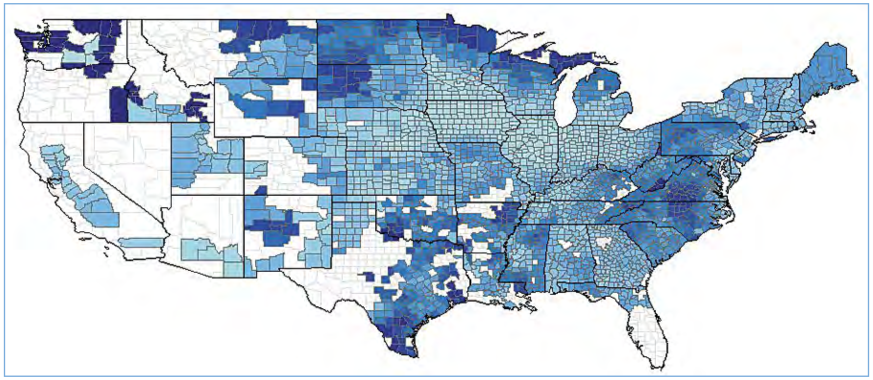
Over the last few years, RMA has been incorporating more satellite imagery into the program. "A majority of the maps we create are located in flood-prone land, which has a higher risk than any other insurance peril," states Oetting. Unlike a Federal Emergency Management Agency map, however, where land is designated as a flood risk or not, RMA is interested in whether a certain land floods only during the specified growing season. Floods that occur in the winter months on a producer's land won't have any impact on the insurance policy for crops planted in the spring because the land is not being used for crops at that time.

Satellite imagery provides a good source to find the extent of floods. "Flooding near major rivers like the Mississippi and Missouri are easy to determine," says Oetting. "But it's harder to determine flood extent and frequency on smaller tributaries. Using GIS to overlay satellite imagery provides an accurate visual of where exactly the flood happened." RMA can check areas that might be designated as high risk when, in reality, they weren't flooded during the actual growing season.

GIS is also used to update maps quickly and help RMA with the appeal process. If a producer doesn't agree with a particular rating class, he can appeal it. For example, a producer may argue that the land he is cultivating is not flood prone. The ability to pull up satellite imagery for the day the river was at its highest during the year and see that, in fact, there was no water on the producer's land allows RMA to rectify the misclassification.

Transparency Leads to Equitable Pricing

Having the maps standardized across the country also helps with creating fair and equitable pricing and makes the process transparent to the producers. RMA has created handbooks for each office so it can standardize editing performed on maps.



Using its rate review mapping tool, RMA can easily visualize how rating components flow across the nation.

This is important, since where crops are physically located dictates the type of coverage farmers are offered. Insurance offers are based on the crop yield for a particular parcel of land. This information is garnered from the producer's production history, the harvest-time futures price set at a commodity exchange before the policy is sold, and the type of crop planted.

The policy will pay an indemnity if the combination of the actual yield and the cash settlement price in the futures market is less than the guarantee.

Using GIS to drill down past the county designation, RMA can designate subcounty insurance offers that are considered high risk, which excludes the insurance history from the calculations that are used to determine the premium rates for the entire county. The end result is a premium rate decrease for most producers, as more high-risk acreage gets reported correctly.

In the past, reviewing premium rates involved colored pencils and large pieces of construction paper on which RMA staff would manually write down all the components of the premium rate by county. Now, GIS can be used to thematically map areas and look for the anomalies. For example, if rates are going down all over Kansas except one county, RMA can not only see the discrepancy quickly but also investigate why. "Trying to answer the why was impossible before," says Oetting. "We would have to find all the documents and papers and then send someone out for a manual check just to chase down the answer. With GIS, everything is linked and very easy to find."

In cases of suspected fraud or abuse, RMA uses imagery to examine a producer's crop for a particular time frame and reconstruct the growing season. Using imagery allows RMA to perform, in essence, forensic remote sensing at any location to see what actually happened on the ground. RMA can pull up the imagery and overlay the digitized map of the farm field boundary. RMA agents can see if the land has been planted as the producer said it would. Since images are captured every 16 days, gathering this visual evidence is important because it provides the evidence needed in a sound, scientific protocol.

"The vast majority of farmers follow the rules," says James Hipple, PhD, physical scientist, USDA-RMA, Office of Strategic Data Acquisition & Analysis. "Remote sensing and GIS are part of the toolbox RMA utilizes in creating an actuarially sound agricultural safety net for America's producers while simultaneously minimizing the amount of fraud, waste, and abuse in the program."

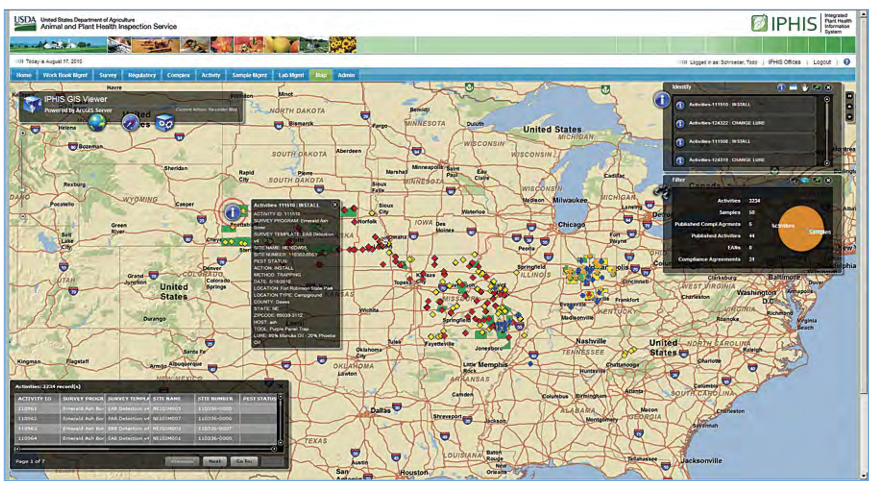
For more information, contact RMA's External Affairs office at rma.cco@rma.usda.gov.

(This article appeared in the Spring 2011 issue of *ArcNews*.)

USDA's APHIS: Sustaining National Food Supply and Security

By Jim Baumann, Esri Writer

With an increasing global population, rapid changes in weather patterns, and greater pressure on international agricultural production and safety, the United States Department of Agriculture (USDA) has expanded its focus on national agricultural issues to encompass a more global perspective. Today, USDA not only analyzes and sustains the needs of the American farmer and consumer through domestic initiatives but also assures the quality of US agriculture to foreign trading partners to protect it from restrictions. Over the years, GIS technology has become an essential tool at USDA to support its efforts.



APHIS users see a comprehensive view of local activities and have the ability to drill down to detailed data at a specific location. Customizable charts provide operational statistics.

Says Todd E. Schroeder, USDA Animal Plant Health Inspection Service (APHIS) director of Business Systems Management, "We have known for some time that while there are immeasurable benefits derived from the increase in domestic and international agricultural trade, it also poses some risks because of the possibility of the accidental introduction of foreign species that can imperil a country's food production capabilities. With our recently implemented enterprise GIS, we are now able to better track potential problems and take remedial action when necessary."

USDA began its use of GIS more than 25 years ago with the development of land-cover and agricultural basemaps from its existing collection of aerial survey data. An enterprise-level GIS license followed, implemented at APHIS. This agency's responsibilities are broad and include protecting and promoting US agricultural health, regulating genetically engineered organisms, administering the Animal Welfare Act, and carrying out wildlife damage management activities. In the event that a pest or disease of concern is detected, APHIS instigates emergency actions with affected states or regions to quickly manage or eradicate the outbreak. This aggressive approach has enabled APHIS to successfully respond to potential pest and disease threats to US agriculture.

To meet its responsibilities, APHIS has implemented GIS-based projects across the country to address various agricultural and natural resource issues. These projects include monitoring the Asian long-horned beetle and emerald ash borer, alien pests that have destroyed millions of hardwood trees, and the development and implementation of the Citrus Health Response Program, which helps the agency advise the US citrus industry and protect it from invasive species.

To be successful, APHIS relies on joint efforts between growers, federal and state regulatory personnel, and researchers. This allows the agency to sustain the sharing and consolidation of data resources in its various initiatives and inform and enhance the decision-making process. Due to the collaborative nature of its work, APHIS needed a nationwide GIS to provide a clear and complete picture of American agriculture and the natural resource landscape that would help the agency maximize the benefit from its various initiatives and meet the goals of USDA. In addition, stakeholders needed real-time data that is secure and easily accessible to be used for planning and operations.

In 2009, APHIS developed the GIS-based, enterprise-wide Integrated Plant Health Information System (IPHIS). The application is currently being implemented state by state for use by all plant health responders. IPHIS provides a real-time system that allows users from any APHIS-supported project to see plant health activities in their district, share data about regional pest infestations, and view national quarantine areas. The system tracks infestations and diseases that impact plants and documents the response. The IPHIS system, with its underpinning GIS technology, helps USDA manage operations, increase efficiencies, and track scientific progress more accurately so that APHIS can quickly respond when the nation's agriculture and forests are threatened.

The IPHIS system's GIS software includes ArcGIS for Server, ArcGIS API for Flex, ArcObjects, and basemaps (street, imagery, relief) from ArcGIS Online (arcgis.com), allowing disparate geospatial data from across the country to be compiled onto a single platform for analysis. This helps APHIS study the data entered by its field crews, providing a program-wide ability to detect and track invasive species of plants and insects. In addition, the GIS allows APHIS to analyze infestation patterns and make clear decisions on its efforts to control invasive species. ArcGIS has also provided APHIS with the ability to perform boundary mapping, route planning, risk analysis, and data filtering and use quality control indicators. Historic GIS data is used to see trends and predict the spread of pests. IPHIS allows users to create customized views of specified projects and provides the ability to drill down to detailed data at precise locations. Customizable charts can easily be generated to visualize operational statistics.

IPHIS has improved communication and transparency by sharing information between other programs and allows access to cooperating entities, such as diagnostic laboratories at state, local, academic, and industry sites. This approach has provided APHIS with a modern, comprehensive, and scalable plant health data management system that promotes sustainable agriculture and safeguards the nation's food supply.

Concludes Schroeder, "The enterprise approach has improved efficiency by integrating and leveraging our existing plant health IT systems and isolated GIS programs, reducing redundancy throughout our network. As a vital part of IPHIS, GIS has helped USDA achieve its goals by improving standardization, accuracy, consistency, and data exchange. In addition, it allows decision makers and scientists to manage current USDA activities and develop and implement long-range plans."

(This article appeared in the Winter 2011/2012 issue of *ArcNews*.)

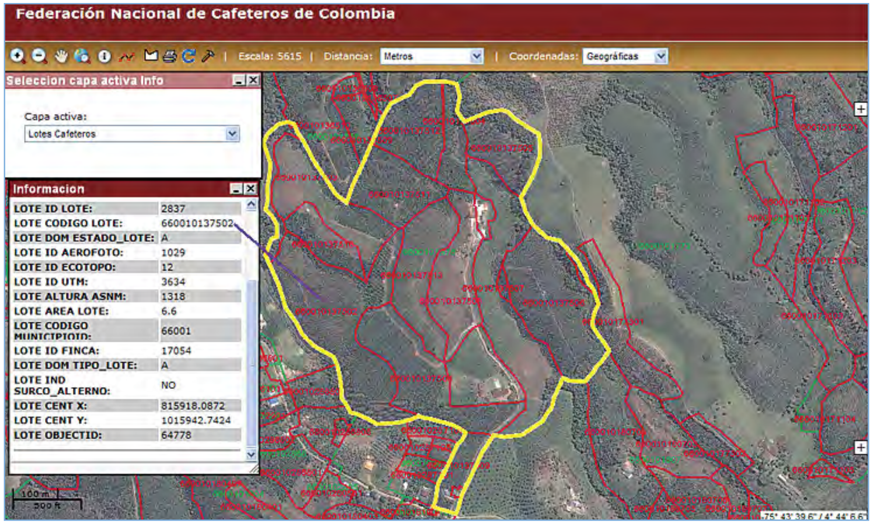
Colombian Coffee Growers Use GIS to Brew Better Crops

By Jim Baumann, Esri Writer

The coffee harvest is a historic component of the Colombian economy that can be traced back more than 300 years to the arrival of Jesuit priests from Venezuela, who began its cultivation. Today, the harvest represents about 10 percent of Colombia's total exports, and the industry employs more than 500,000 people in its coffee production operations. Most farms are small producers, with less than five hectares of coffee trees under cultivation.

In 1927, the Federación Nacional de Cafeteros de Colombia (FNC) was formed to represent the interests of the small coffee growers in the country. However, because of the large number of coffee growers, FNC faced a problem in centralizing the data collected from these farms. This impacted the federation's ability to negotiate better coffee prices based on coffee yield predictions across the entire country.

To improve its forecasting capabilities, FNC conducted an extensive survey of coffee production in Colombia nearly 20 years ago. The resultant Encuesta Nacional Cafetera (ENC) is the standard on which the regularly updated Sistema de Información Cafetera (SICA) is still referenced today. SICA is a system that provides the fundamental data infrastructure



An individual parcel is selected within FNC's coffee crop sample area. Displayed data includes its latitude-longitude location and various identification codes.

and strategic information used in the design, formulation, and tracking of Colombian coffee farming. The current version of SICA has been based on ArcGIS Server software since 2008 and is used for online information analysis, planning, sustainability policies, decision making, competitive analyses, environmental monitoring, crop forecasting, farm registration, and quality assurance. FNC had been using ArcGIS Desktop software for many years and naturally selected ArcGIS Server to upgrade SICA.

The model ENC survey included a collection of aerial photographs that were orthorectified using Esri's GIS software for inclusion in the original SICA geographic database. Today, the ArcGIS Server Image extension is used to manage and publish the large volumes of geospatial imagery that it collects from remote-sensing sources, such as orthophoto mosaics, satellite imagery, and aerial photography, for inclusion in SICA. The technical staff at FNC uses ENVI image processing software for multitemporal analysis and research on the collected imagery.

Crop forecasting is carried out using ArcGIS analytic tools on SICA data, which includes georeferenced samples collected by FNC field service teams within specified cultivated areas. To conduct the biannual sampling process, more than 1,000 field technicians harvest both ripe and unripe beans from coffee trees in each specified area. The beans are counted and weighed, then statistical processes are applied to extrapolate crop estimates for the succeeding six-month period. After completing their samplings, the FNC field service teams upload the crop yield data into the SICA geodatabase through either an Internet-based server application or a custom-built ArcGIS Mobile application. Because the FNC GIS is Web based, near real-time updating of the SICA database can now be performed.

The collected data is also analyzed by Cenicafé, FNC's research center, and the federation provides reports to its members regarding its critical findings. Current research topics include erosion management; soil remediation; and the multiple ways in which the coffee harvest is affected by changing environmental factors, such as variations in rainfall and temperatures.

FNC also monitors the socioeconomic issues that affect the coffee farmer. SICA maintains information regarding the educational opportunities for FNC members, the condition of the infrastructure in their towns and villages, and the health care facilities available to them.

GIS has proved to be an invaluable resource for the Federación Nacional de Cafeteros de Colombia and its constituent farmers. The technology not only provides a wide range of services related to coffee crop forecasting and associated research but also allows the federation to track the quality of life of its members. This provides a compelling example of the power of GIS and how it can help improve the socioeconomic conditions of people throughout the world.

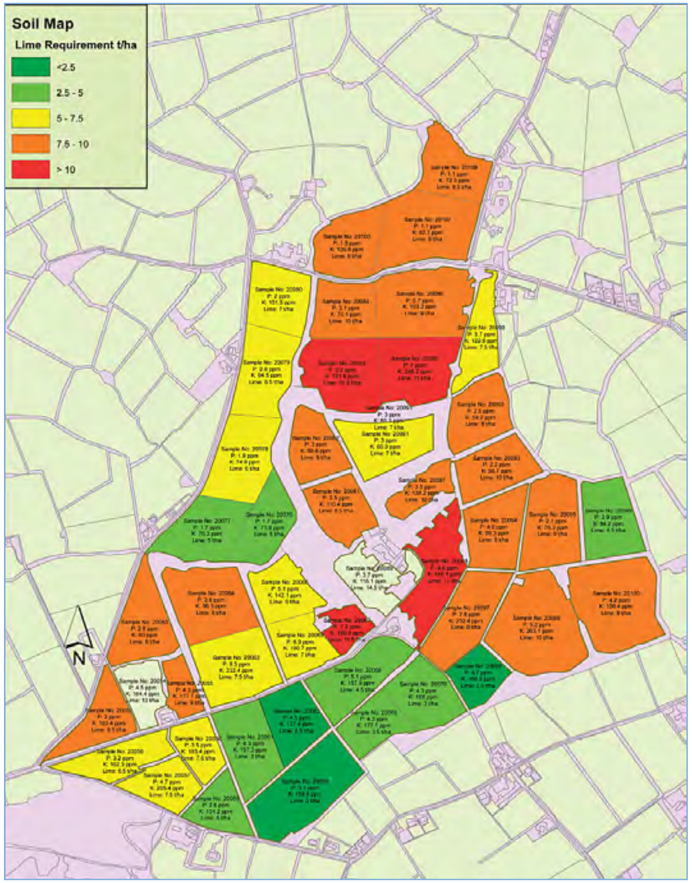
(This article appeared in the Summer 2010 issue of *ArcNews*.)

Irish Agricultural Catchments Programme Protects Water Quality While Supporting Productive Agriculture

By Sarah Mechan, Edward Burgess, and Réamonn Fealy

Situated on the western fringe of Europe and subject to the moderating influence of the Atlantic Ocean, Ireland is fortunate to have a temperate maritime climate that is particularly suited to grassland agriculture. With conditions facilitating a grass growing season that extends almost throughout the entire year, grass-based dairy and beef production constitute the primary agricultural sectors. From a land area of 6.9 million hectares, 4.2 million hectares are used for agriculture. With 80 percent of agricultural area devoted to pasture and hay and grass silage, 10 percent to rough grazing, and the other 10 percent to tillage, it is little wonder that Ireland is known as the "Emerald Isle."

However, as in other countries, issues around maintaining a high-capacity, productive agricultural sector while ensuring a sustainability-based farming approach remain a focus for all stakeholders. In partnership with farmers and other stakeholders, the Irish Agricultural Catchments Programme (ACP) is mandated to support productive agriculture while protecting water quality. It is funded by the Irish Department of Agriculture, Fisheries and Food and run by Teagasc, Ireland's Agriculture and Food Development Authority. ACP advisers provide an intensive advisory and planning service to farmers in small river catchment areas (500 to 2,900 hectares) with support from their colleagues



A soil index map indicating the lime requirement and concentrations of phosphorus and potassium in sampled fields.

both locally and nationally. They help the farmers improve their profitability and implement the necessary agri-environmental measures contained in the National Action Programme recently introduced under the European Union (EU) Nitrates Directive. This directive aims to protect water quality across Europe by preventing nitrates and phosphorus from agricultural sources from polluting surface and groundwater. ArcGIS software-based applications have played a primary role in facilitating both the establishment and operation of the program.

Catchment Selection Application

The selection of catchments was influenced by EU guidelines that indicate monitoring efforts should be concentrated in "areas of intensive crop and livestock production . . . with elevated nitrate concentrations . . . adjacent to existing or projected eutrophication areas . . . with similar land use, soil type, or agricultural practice." Thus, it was necessary to devise a method for selecting small catchments (from 400 to 1,200 hectares) that were farmed intensively, either predominantly grassland or arable, and at risk of high phosphorus or nitrogen losses from land into the rivers that drain them.

Given the spatial and environmental context of the task of candidate catchment selection, the role for a GIS-based methodology was immediately obvious. Given a long association with Esri products and a significant investment by the Spatial Analysis Unit in Teagasc in both ArcGIS Desktop and ArcGIS Server software, Teagasc chose ArcInfo to build a geodatabase to hold and manage the range of datasets required for the task, which were supplied from a diverse group of government departments and agencies. Oracle was chosen as the main database solution for the operational stage of the project.

In beginning the selection process, Spatial Analysis Unit staff first examined a national catchment boundary dataset of approximately 6,000 catchments to generate a list of 1,300 possible small river catchments based on size and stream order. These were further divided into two broad categories—grassland and arable cropping. The data analyzed included land use, forestry, area of peat, livestock density, nonagricultural land use, arable cropland, forage areas, housing density, geology, and soil types. A Multiple Criteria Decision Analysis (MCDA) approach was employed in the analysis using the onboard attribute table tools already available in the ArcInfo processing environment.

After detailed consultation with a broad range of experts from scientific, policy, and farm sector backgrounds, various selection criteria were chosen and given weights, reflecting the suitability of the catchments for monitoring by ACP. The internal attribute tables of each of these input parameters were reclassified into appropriate ranges, and these, too, were ranked according to selection suitability. A weighted summation provided an ordered list of catchments ranked by their suitability. The ArcGIS Spatial Analyst extension was used to model the risk at the catchment level of nitrogen or phosphorus moving from land to water. This model implemented a risk assessment procedure devised at the national level for formal reporting to the European Commission on the Water Framework Directive. ACP had at its disposal the most detailed national-scale datasets, and the risk model developed for the program is the most highly resolved available nationally.

The model is primarily based on soil drainage and subsoil hydrologic characteristics. Generally, more poorly drained soils have a greater risk of phosphorus loss through overland flow or runoff, while the more freely drained soils have a greater risk of nitrogen loss through leaching down through the soil. Of the 1,300 eligible catchments initially identified, a short list of 50 top-ranking arable and grassland catchments was drawn up. ACP staff visited these catchments to assess their physical suitability as study sites. Six catchments were selected for detailed study—four that were predominantly grassland and two with a high proportion of arable farming. The GIS-MCDA approach was shown to be particularly suitable to the selection task, and its implementation in ArcInfo proved highly efficient in handling the large number of input datasets and processing requirements.

Presentation of Soil Analysis Results

Upon selection of the catchments for monitoring purposes, ACP needed to establish baseline soil nutrient levels for each catchment area. To achieve this, ACP undertook a field-based sampling campaign to establish soil nutrient status. To accurately represent the variation in soil nutrients across the catchments, high-resolution soil sampling was employed (the average area per sample was approximately two hectares). This high-resolution soil nutrient data facilitated the preparation of accurate nutrient management plans for catchment farmers. However, there was a risk that farmers would find these plans difficult to interpret given the high level of detail they contained and the large number of land management units (whole fields or subfield areas). To make the interpretation of the plans easier, ACP decided to develop clearly labeled, color-coded maps. Each field and sample area was digitized and allocated a unique code as part of the catchment digitizing process. The sample area codes were then entered into a Laboratory Information Management System, along with the corresponding soil sample code. This enabled the results to be linked back to produce intelligent maps. For each farm within the catchment areas, color-coded maps labeled with unique soil sample numbers can now be produced.

Maps illustrated by different colors, displayed in each sample area, can easily be produced in ArcGIS, which shows the phosphorus, potassium, and lime requirements of the crops to be grown. A set of maps can now be printed for each farm in less time than it would take to print the original soil analysis report. This analysis helps each farm increase its crop yield through targeted application of nutrients to match crop requirements and minimizes the leaching of nutrients (and effective loss of a farm resource) into local watersheds. The most satisfying aspect is the feedback from the farmers. They find the maps very informative and easy to use, leaving the advisers more confident that nutrient management on these farms will be carried out in an accurate and informed manner. This technology can be used to overlay many years of soil analysis results to track temporal changes in soil fertility and nutrient management.

About the Authors

Sarah Mechan is data manager for ACP. Her core role within the project is to develop and maintain an information management system to ensure the most efficient data capture and integration from multiple sources. Edward Burgess is an adviser to the farmers in the Castledockerell and Ballycanew catchments. He provides an advisory service to assist farmers' compliance with National Action Programme measures. Réamonn Fealy was part of the initial working group that proposed ACP, and he designed the catchment selection procedure described here. The authors would like to acknowledge the contribution to this article by David Wall, ACP soil scientist, and Ger Shortle, program manager.

More Information

For more information, visit the Agriculture and Food Development Authority Web site at www.teagasc.ie/agcatchments.

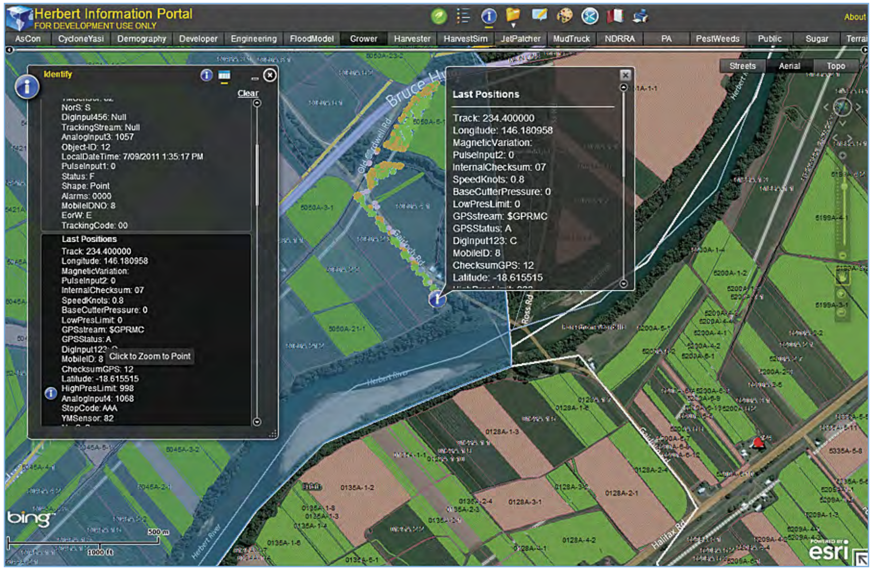
(This article appeared in the Fall 2010 issue of *ArcNews*.)

Enterprise Solution a Sweet Reward for Australian Sugarcane Farmers

Technology Supports Sustainable Development of Local Industry

By Jim Baumann, Esri Writer

The roots of cooperative sugarcane cultivation in the Herbert River catchment basin in North Queensland, Australia, can be traced to the early 1880s, when six small-area landowners formed the Herbert River Farmers Association. Shaped by the social and economic conditions of the day, the landowners believed that both the sugarcane industry and local residents would be better



Herbert Information Portal showing harvested areas and cane harvester movements.

served by cooperative farming rather than the plantation model that had flourished in the area for the preceding 20 years.

Two years later, Colonial Sugar Refining Company (CSR), the primary sugarcane processing company in the region, offered agreements to the newly formed association to centrally mill its cane. In 1891, CSR subsequently subdivided its Homebush Estate into small farms, which it leased to local farmers with an option to buy.

Though farming methods in the Herbert River catchment have changed greatly during the succeeding 130 years, its cooperative nature has grown even stronger with the founding of Herbert Resource Information Centre (HRIC). Established in 1996, this nonprofit organization supports the sustainable development of the sugarcane industry in the Lower Herbert River catchment through technological innovation and is responsible for building community networks between local industry, government, and residents.

Shortly after its formation, HRIC conducted a mapping project of the Herbert River floodplain. The results of the project proved difficult to disseminate to both the HRIC coalition and the local farming community. Members decided to implement a GIS that would allow HRIC to better analyze local sugarcane farming and distribute its findings. Consequently, HRIC launched Herbert Information Portal (HIP), a collaborative GIS using Esri software.

Today, HIP has evolved into an enterprise system built on ArcGIS for Server and ArcGIS for Desktop and extensions. The GIS is web based so that HRIC partners and local farmers have easy access to information. HIP supports most of the critical business processes in the region's sugar industry supply chain by acting as the catalyst for implementing precision farming technology, from improved harvesting and transport management to more efficient milling operations. Applications include Cane Mapping and Management, Real-Time Cane Harvester Monitoring, Sucrogen Rail Safe Integration, and Cane Yield Monitoring systems. These applications use GIS to promote efficiency, productivity, and improved environmental outcomes for HRIC partners and sugarcane growers.

Because the Herbert River catchment basin is sandwiched between two environmentally protected areas—Wet Tropics World Heritage Area and Great Barrier Reef Marine Park—the cane-growing industry uses the tools provided by HRIC to improve productivity while monitoring and reducing impact on the environment.

"Though initially established as a technology center," says Raymond De Lai, HRIC manager, "we quickly realized that the most significant value that HRIC could provide to our partners was the opportunity to build and enhance relationships among people and organizations. We are strongly focused on building trust, commitment, and cooperation through a shared vision among our partners and the wider community."

The partners in the HRIC project include local government representatives from Hinchinbrook Shire Council; the CSR group that refines and transports the processed sugarcane; and Terrain

Technology has come a long way for sugarcane farmers in the Herbert River catchment basin of North Queensland, Australia.

(Photo courtesy of Derek Tickner.)

Natural Resource Management, a nonprofit agency that builds regional consensus for natural resource management. Also included in the management coalition are representatives from the Bureau of Sugar Experiment Stations and Herbert Cane Productivity Services, which provide research, development, and extension services to the sugarcane industry.

"For us, the advantage of a partnership approach to an enterprise GIS is the sharing of its cost, risk, and—of course—the benefits," says De Lai. "Any one of our HRIC partners would find it very difficult to fund their own system. Together, we are able to buy into a large enterprise GIS infrastructure, data management processes, capacity building, and a relationship with our partners that provides benefits beyond GIS projects."

The mutual support and interaction between HRIC and the community is essential because sugarcane production in the area is a complicated process that includes a number of well-coordinated steps, from planting to harvesting. The process is underpinned by the automatic collection and transmission of spatial data to HIP for analysis and decision making.

"Our sugarcane growing and harvesting procedures require a high level of interdependence within the community because the process is not vertically integrated, except for the milling and transport," says De Lai. "We rely a great deal on the growers to provide regular updates on the status of their fields."

Because sugar production can be increased with better management of harvest scheduling and decision making based on regional variations in soil, irrigation, and climatic conditions, the growers have fitted their harvesting equipment with onboard computers, electronic logbooks, base-cutter height sensor kits, and yield monitors. Data is automatically collected by the sensor systems installed on the tractors and other field equipment and transferred to HIP for processing and analysis with ArcGIS.

When analyzing yield variation within a field, the system suggests how growers may be able to reduce their costs through varying farm inputs. By closely managing irrigation and monitoring climatic conditions, the optimal harvesting time can be determined to maximize the sucrose content in the sugarcane. An increased sucrose yield increases the profitability of the harvest.

Since harvesting is the costliest activity on a sugarcane farm, it is important to keep the cane harvesters in constant operation during the cutting season. This is facilitated, in part, through the use of Twitter, the social networking site. Farmers Tweet the status of the harvester in their field so that the owner of the subsequent field knows exactly when the equipment will arrive to begin the next job. It is expected that this concept will be used for other projects in the near future, such as identifying the location of cane trains and broadcasting the estimated times of arrival.

"Using enterprise GIS has allowed us to integrate our various data inputs and provide real-time access for managers and decision makers," De Lai concludes. "In development terms, we are doing things now in hours and days that would previously have taken us weeks and months. Technically, we can put in place anything we envision at the moment. Our challenge is to identify the business models that are sustainable and support those opportunities through GIS."

(This article appeared in the Winter 2011/2012 issue of *ArcNews*.)

Sustainability in Africa

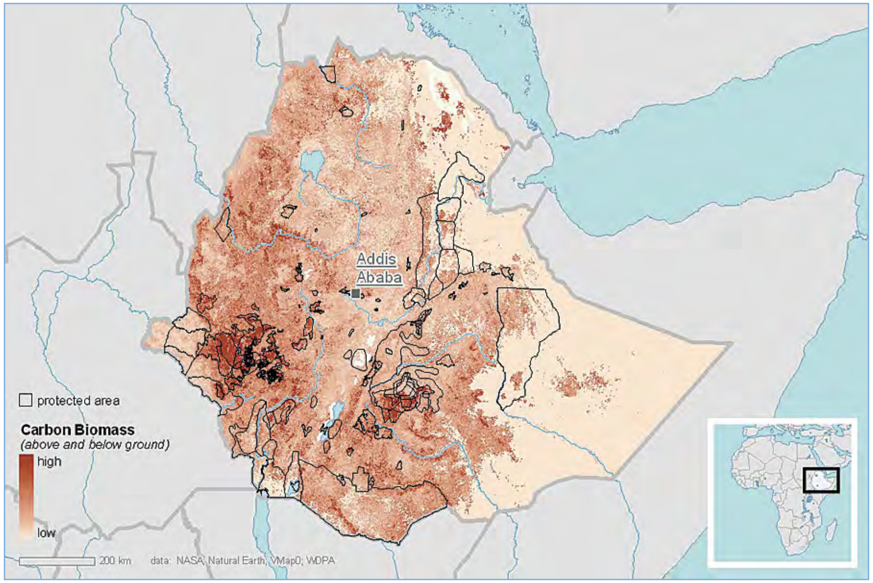
By Peter A. Seligmann and Sandy J. Andelman, Conservation International

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

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

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

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



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

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

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

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

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

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

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

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

Measuring Sustainability: Getting the Metrics and Measurements Right

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

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

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

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

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

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

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

The harvesting of amaranth greens.

(Photo courtesy of Conservation International. Copyright © Benjamin Drummond.)

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

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

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

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

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

Looking Ahead to Increased Sustainability

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

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

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

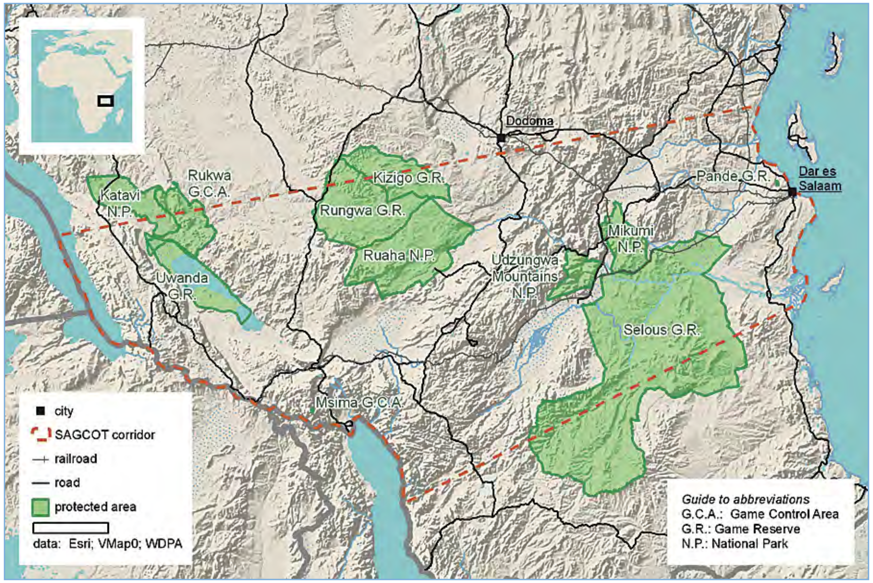
Without concerted investments in a framework with the right metrics, indicators, and data to track changes in ecosystem services and human well-being, gains in food production are unlikely to be sustainable in the long run. At worst, they may unintentionally degrade the environment.

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

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

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

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



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

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

Vital Signs Africa

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

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

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

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

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

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

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

The Geospatial World of Conservation International

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

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

Will Breadfruit Solve the World Hunger Crisis?

New Developments in an Innovative Food Crop

By Matthew P. Lucas and Diane Ragone, National Tropical Botanical Garden

A map can be a powerful visual tool, but can a map help solve world hunger, rejuvenate agricultural soil, and prevent mosquito-borne infections? Can a map help slow global warming and spur sustainable economic development in tropical regions around the world? Perhaps a map alone can't do these things, but a map can help display the real potential of a very special tree, the breadfruit.

Different varieties of breadfruit are conserved in the world's largest collection of breadfruit at the Breadfruit Institute in Hawaii.

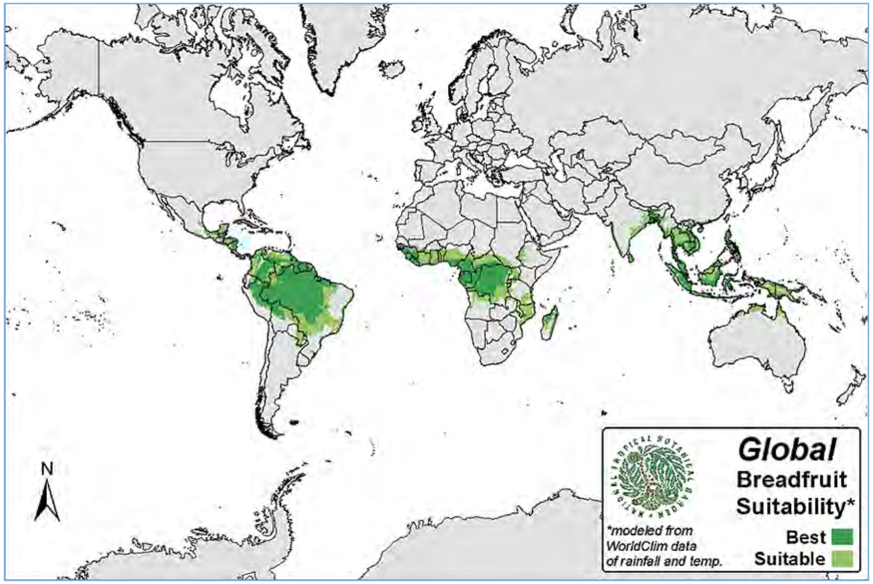
(Photo credit: © Jim Wiseman, courtesy of the Breadfruit Institute)

Breadfruit (*Artocarpus altilis*) is a tropical tree originally from Papua New Guinea with a rich and storied history. This starchy staple crop has been grown in the Pacific for close to 3,000 years and was first introduced to other tropical regions more than 200 years ago. The trees are easy to grow and thrive under a wide range of ecological conditions, producing abundant, nutritious food for decades without the labor, fertilizer, and chemicals used to grow field crops.

These multipurpose trees improve soil conditions and protect watersheds while providing food, timber, and animal feed. All parts of the tree are used—even the male flowers, which are dried and burned to repel mosquitoes. Because of its multiple uses and long, productive, low-maintenance life, breadfruit was spread throughout the tropical Pacific by intrepid voyagers. Hawaii is one of the many island chains where breadfruit, or *ulu* in Hawaiian, was cultivated as a major staple. It is fitting that now Hawaii is home to the headquarters of an organization devoted to promoting the conservation and use of breadfruit for food and reforestation around the world.

The Breadfruit Institute, within the nonprofit National Tropical Botanical Garden (NTBG), is a major center for the tree's conservation and research of more than 120 varieties from throughout the Pacific, making it the world's largest repository of breadfruit. As a result of this work, the institute has received requests from numerous countries seeking quality breadfruit varieties for tree-planting projects. To address this need, the Breadfruit Institute has developed innovative propagation methods, making it possible to produce and ship thousands, or even millions, of breadfruit plants anywhere in the world.

These breadfruit tree-planting projects can help alleviate hunger and support sustainable agriculture, agroforestry, and income generation. Most of the world's one billion hungry people live in the tropics—the same region where breadfruit can be grown. However, as Dr. Diane Ragone, author and director of the Breadfruit Institute, has learned, stating these facts and illustrating them are two very different things. A strong realization is made when a person sees the data from the United Nations Food and Agriculture Organization global map on world hunger coupled with a map showing areas suitable for growing breadfruit.



Map showing zones of "best" and "suitable" growing conditions for breadfruit.

It was originally this type of powerful visual aid Ragone wanted when she began working with NTBG's GIS coordinator and coauthor Matthew Lucas. To create such a map, Lucas began by constructing a model within ArcGIS using WorldClim 30-second resolution global raster datasets of interpolated climate conditions compiled from the past 50 years (Hijmans et al. 2005). With the GIS, monthly rainfall and temperature data was condensed into total annual rainfall, mean annual temperature, and minimum and maximum annual temperature. Then, the annual climate data was reclassified.

"Suitable" and "best" ranges of rainfall and temperature were identified after referring to the breadfruit profile written by Ragone for *Traditional Trees of Pacific Islands* (Elevitch 2006). The best ranges in mean temperature and rainfall were given a value of 2, whereas suitable conditions were given a value of 1; conditions that were deemed too low or high were given a value of -10. ArcGIS was used to combine all the reclassified climate datasets. The final output resulted in a global dataset that now displayed areas deemed unsuitable for growing breadfruit as < 0, areas assumed suitable with a value of < 4 and > 0, and best areas with a value of 4. This data was displayed in combination with 2011 Global Hunger Index scores entered into a vector dataset of countries. The resultant map helps the viewer see the real potential breadfruit development could have for tropical regions.

With this new visual aid completed, Ragone and Josh Schneider, cofounder of Cultivaris/Global Breadfruit, a horticultural partner that propagates breadfruit trees for global distribution, attended the World Food Prize symposium in October 2011. The breadfruit suitability map was shared with Calestous Juma, professor of the practice of international development and director of the Science, Technology, and Globalization Project at the Belfer Center for Science and International Affairs at the Harvard Kennedy School. Juma has extensive experience and contacts in Africa.

The map was also shared with the former president of Nigeria, Olusegun Obasanjo. It was at Obasanjo's invitation that Schneider visited Nigeria and met with government officials and researchers to discuss breadfruit planting projects. Due to the relatively fine scale (1 km) of the original datasets, a more detailed map of Nigeria showing areas suitable for growing breadfruit, along with roads and cities, was an invaluable tool during discussions.

The World Food Prize meeting also spurred other similar country-specific maps that have been created and shared with organizations and individuals working in Haiti, Ghana, Jamaica, Central America, and China. The maps provide government officials, foundations, and potential donors with clear information about the potential of breadfruit in specific areas. The maps have spurred the question, What other countries are best suited for growing breadfruit? ArcGIS was used to combine the breadfruit suitability data with a vector layer of country borders. This not only resulted in a list of countries that could possibly grow breadfruit but also made it easy to identify and rank the amount of area each country has that is suitable and best for growing breadfruit.

It became clear that this map, the data, and the ArcGIS methodology used to construct it provided not only a powerful

Breadfruit is extremely productive, producing an average of 150–200 and up to as many as 600 nutritious fruits per season.

visual aid but also a useful research tool. Armed with these maps and the information they convey, Lucas and Ragone are continuing to pair what has been learned about breadfruit cultivation with ArcGIS to help understand and display future breadfruit potential. They are currently working on a climate change analysis that uses predicted climate datasets of various future climate models and scenarios in an attempt to quantify areas that would have the highest likelihood of sustainable breadfruit development. They are also working on publishing an online map displaying global breadfruit growing potential. Finally, it is the hope of the Breadfruit Institute and NTBG that future breadfruit development will be expanded and that ArcGIS will help guide potential breadfruit-growing countries in planning and implementing planting projects of this very special tree.

About the Authors

Matthew Lucas is the GIS coordinator for the Conservation Department at the National Tropical Botanical Garden. As a graduate of the University of Hawaii, Hilo, Department of Geography, Lucas hails from a conservation background where he uses models and maps to guide more efficient decision making and problem solving. Diane Ragone, PhD, is director of the Breadfruit Institute at the National Tropical Botanical Garden. She is an authority on the conservation and use of breadfruit and has conducted horticultural and ethnobotanical studies in more than 50 islands in Micronesia, Polynesia, and Melanesia.

For more information about the Breadfruit Institute and NTBG, visit www.ntbg.org/breadfruit. To help support the work of the institute and breadfruit tree-planting projects, visit ntbg.org/breadfruit/donate/plantatree.php. For more information on Global Breadfruit and how you can help, visit www.globalbreadfruit.com.

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

More Crop per Drop

GIS-based water requirement maps optimize water use

By Jim Baumann, Esri Writer

Existing GIS-based tools used by a Netherlands-based company that helps optimize water use are being ported to a standardized ArcGIS platform.

Optimizing the irrigation of crops saves water.

Two well-established companies in the Netherlands—WaterWatch and Basfood—formed eLEAF to support global solutions for agriculture and the environment with data they collect on vegetation, water, and climate. WaterWatch previously developed PiMapping technology, a family of GIS-based tools that delivers more than 50 data components.

"In the past, the efforts to expand agricultural productivity have focused on the land, commonly measured as a yield per hectare," said Maurits Voogt, manager of eLEAF Competence Center. "However, with the increasing global scarcity of water resources, the focus is shifting away from the land on which the crop is grown and to the productivity of the water applied to the crop, or a yield per cubic meter."

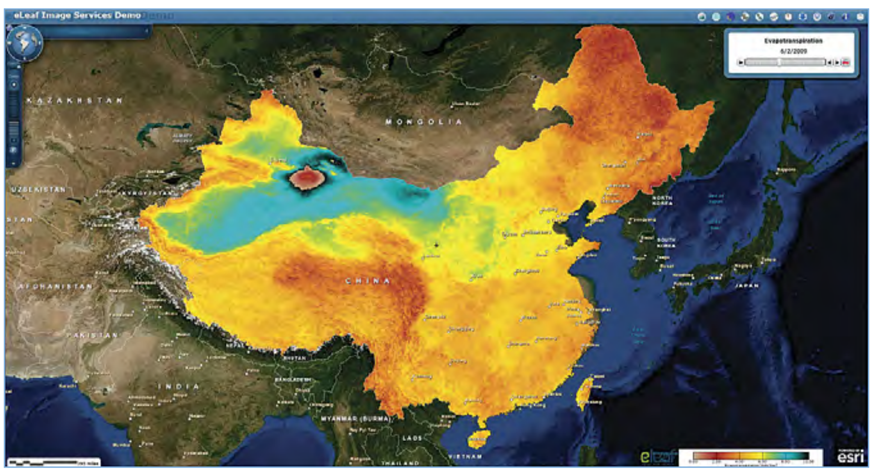
Optimizing crop water use efficiency requires quantitative measurements of crop water consumption. The physical process behind crop water consumption is called evapotranspiration. It is the combination of plant transpiration (the loss of water vapor from plants) and surface evaporation.

Utilizing Remote-Sensing Data

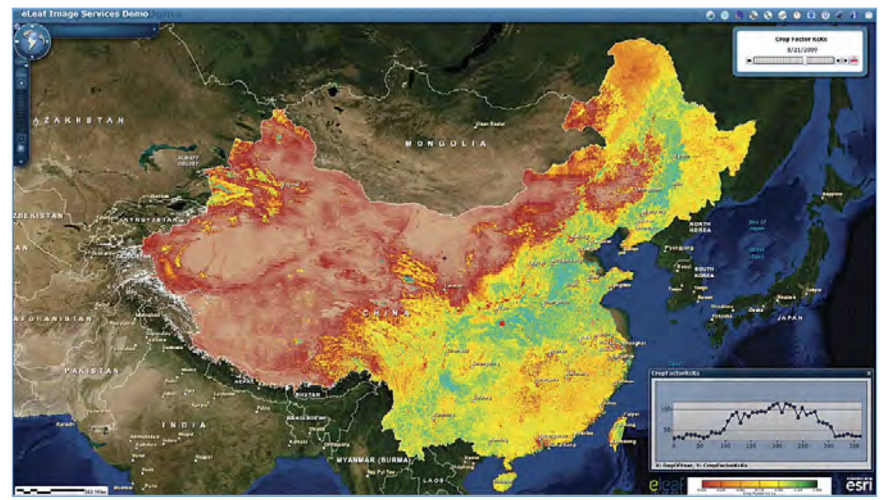
During the mid-1990s, professor Wim Bastiaanssen, a water resources modeling and remote-sensing specialist and founder of WaterWatch, developed the Surface Energy Balance Algorithm for Land (SEBAL) model to calculate crop water consumption from remote-sensing data. The model measures the energy balance that specific plants in a defined area require to sustain the hydrologic cycle. Basically, the energy driving the hydrologic cycle is equal to the incoming energy from the sun minus the energy reflected back into space and the energy used to heat the surrounding soil and air.

The model uses satellite imagery (spatially distributed, visible, near-infrared, and thermal infrared data) that includes the albedo (solar reflection coefficient), leaf area index, vegetation index, and surface temperature. This complex algorithm calculates evapotranspiration on a pixel-by-pixel basis to determine the optimum amount of water needed to sustain healthy plant life in any part of the world. It can also calculate the biomass production (total plant life) in a specified area and soil moisture in the root zone.

Bastiaanssen established WaterWatch to pursue his research in water resource modeling and remote sensing. The framework WaterWatch developed for PiMapping is based on the SEBAL model. Along with supporting algorithms, PiMapping provides essential meteorologic input data such as wind speed, humidity, solar radiation, and air temperature. Combining those inputs with remote-sensing data, PiMapping generates weekly updates on



The sum of evaporation and plant transpiration, evapotranspiration is calculated using satellite images and meteorological observations to determine optimum water needs for plant health. This analysis, and the others shown, were calculated in eLEAF and mapped in ArcGIS for a specified time period.



The amount of water required for crop under irrigation is calculated by multiplying the reference evapotranspiration by a crop coefficient (Kc).

biomass production, water productivity, crop water requirements, root-zone soil moisture, and CO_2 intake.

PiMapping Moves to ArcGIS

eLEAF is working with Esri's Professional Services team to port PiMapping's complex tools to a standardized ArcGIS platform. "The solution will leverage Esri's cloud infrastructure, opening many new exciting opportunities for data analysis and dissemination," said Bastiaanssen.

Time-series data collected from this framework is plotted in ArcGIS to create evapotranspiration and biomass production maps. Benefits are substantial and include the estimation of water requirements for different agro-ecosystems, drought monitoring, the identification of areas for possible water savings, and the potential volume of such savings. "Compelling visualizations of our results are essential to get the message across," Bastiaanssen explained. "In our day-to-day consulting work, we have seen substantial productivity increases thanks to the great mapmaking features of Esri's products."

Because they are GIS based, evapotranspiration maps can also be combined with land-use and biomass coverages. Combining these maps provides a great deal more information, such as the amount of water use by land-use class; the boundaries of areas where water consumption can, and cannot, be controlled; the impact of changes in land use on downstream water availability; crop water productivity; and the amount of water that can be saved while the same production levels are maintained.

"From our analyses, you can determine how much water is available in a specified area, what yield you can expect from the water that is available for your crops, and how efficiently water is used. This will enable farmers to produce more food in a sustainable way," said Voogt.

ArcGIS in Cloud Delivers eLEAF Data

ArcGIS hosted in the Amazon cloud delivers eLEAF data to clients. "We are in the process of creating a worldwide database from our analyses that anyone can access using very simple web services," said Ad Bastiaansen, cofounder of eLEAF. "ArcGIS has the features we need to integrate with our clients' systems."

Once data is processed and quality checked, it is posted in eLEAF's data warehouse.

eLEAF's biomass production analysis for northern India, mapped using ArcGIS, is displayed on a smartphone.

ArcGIS for Server exposes the data in multiple formats, such as Open Geospatial Consortium, Inc. (OGC), web services, and through an image server so eLEAF can feed websites, as well as smartphone applications, that accommodate customer demands. To afford easy access to its global databases, eLEAF also provides its service via ArcGIS Online. "ArcGIS Online is a wonderful platform. People can experience our products and easily integrate them in their maps," added Bastiaansen.

The rollout of eLEAF's ArcGIS Online service has begun in South Africa. As new data is acquired, the service will expand to the entire African continent, then to the Middle East. Updates are applied to previously collected data on a weekly basis so users' decisions are based on current data.

"Initial reports from South Africa indicate that the eLEAF service has been well received by agronomists, particularly because of its portability to the field," Bastiaansen said. "We are happy that our efforts will help local farmers increase their productivity."

(This article appeared in the Winter 2013 issue of *ArcUser*.)

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