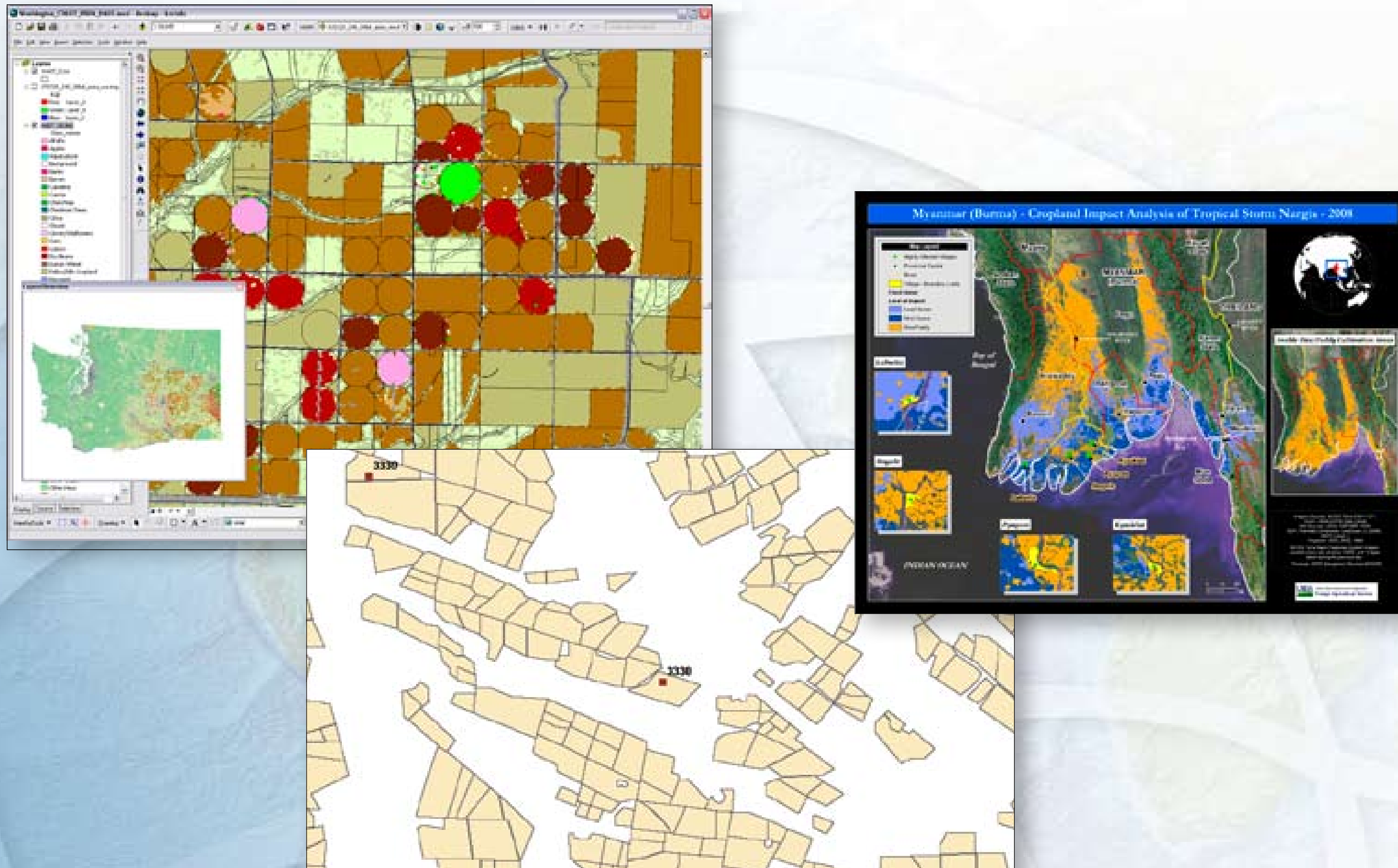
GIS Best Practices

GIS for Agriculture



June 2009

Table of Contents

What Is GIS?

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

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

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

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

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

GIS for Agriculture

Balancing the inputs and outputs on a farm is fundamental to its success and profitability. The ability of GIS to analyze and visualize agricultural environments and workflows has proved to be very beneficial to those involved in the farming industry.

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

While natural inputs in farming cannot be controlled, they can be better understood and managed with GIS applications such as crop yield estimates, soil amendment analyses, and erosion identification and remediation.

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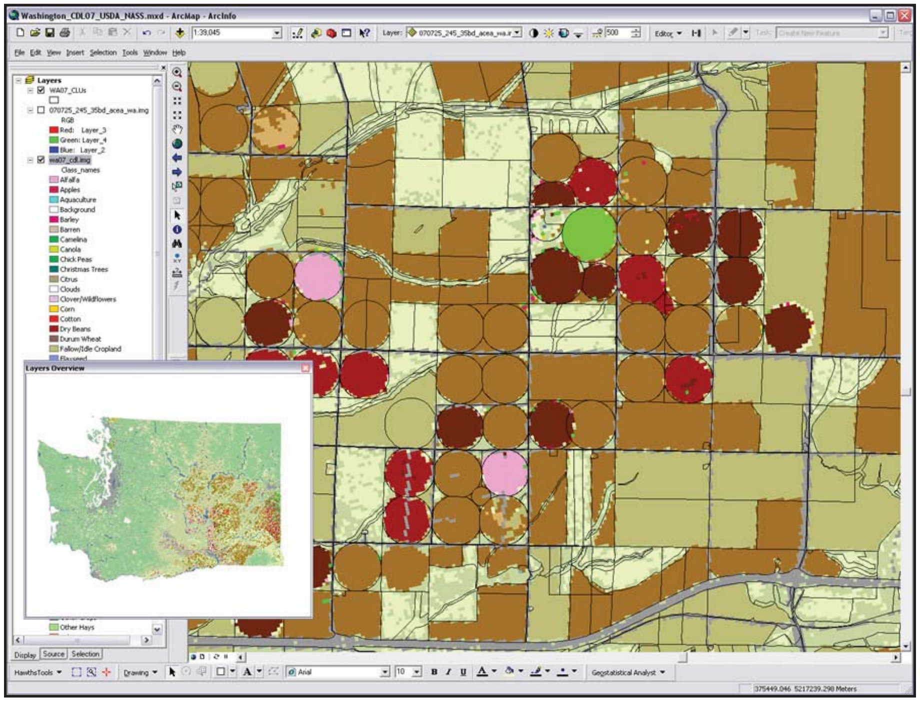
Agribusiness Grows with Crop-Specific Maps

U.S. Farmland Data Layer Available for Download

By Jessica Wyland, ESRI writer

Crop-specific maps, created by combining survey data and satellite images, literally provides the lay of the land for farmers and agribusinesses such as seed and fertilizer companies. Corn, soybean, rice, and cotton crops grown in the Corn Belt and Mississippi River Delta areas of the United States are mapped extensively in the Cropland Data Layer (CDL) now available for download or on DVD from the United States Department of Agriculture/National Agricultural Statistics Service (USDA/NASS).



The state of Washington is shown in the NASS 2007 Cropland Data Layer with USDA/Farm Service Agency with Common Land Unit data overlay.

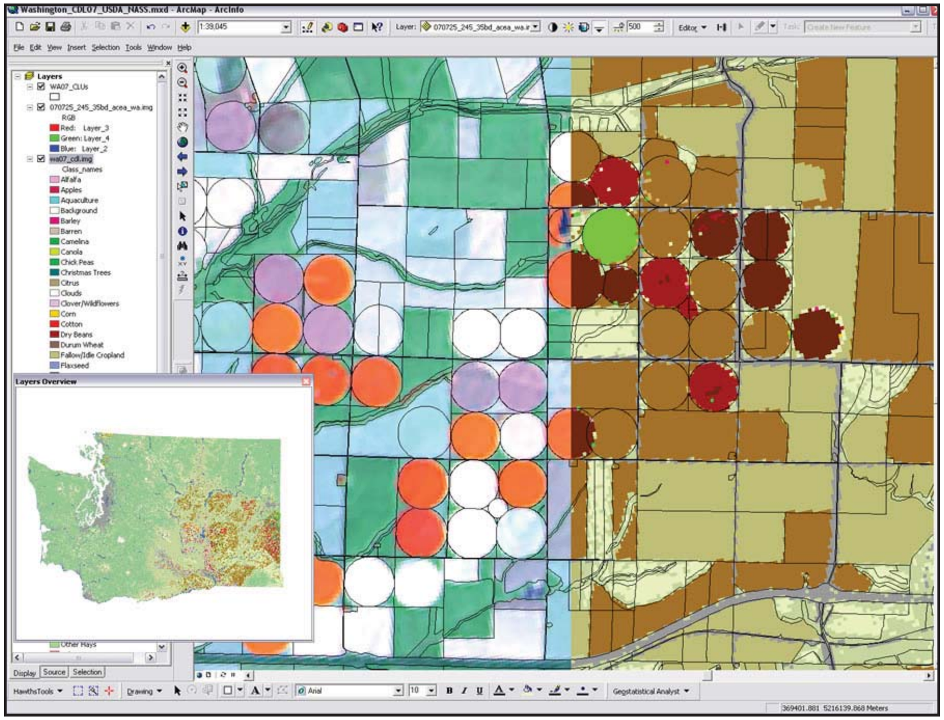
Geographic information system (GIS) software from ESRI is used to prepare and manage agricultural data and build geospatial snapshots of cropland.

"There are many possible uses for the Cropland Data Layer inside and outside the farming community," said Rick Mueller, a GIS expert with NASS. "CDL can be leveraged in a GIS to perform spatial queries against other enterprise GIS data layers. It can be extracted and masked out so public or private entities can focus solely on their own interests."

Enhancing a GIS with land-cover data layers has proved helpful to crop growers' associations, crop insurance companies, seed and fertilizer companies, farm chemical companies, libraries, universities, federal and state governments, and value-added remote-sensing/GIS companies. Agribusinesses refer to the data to site new facilities for retail supplies and equipment, route transportation of crops and goods, and forecast harvests and sales. A fertilizer company, for example, can use CDL to better anticipate how much fertilizer will be needed in specific regions. The data is also used by pesticide companies to study pest migration trends and pesticide applications. It is used by farmers and conservationists to perform risk assessment of wildlife habitat, crop stress, and blight locations. Educators determine research locations based on crop density distribution and develop ecosystem models with CDL figures and images.

For each state in the Corn Belt and Mississippi River Delta areas, CDL provides the categorized raster data along with accuracy statistics and metadata by state. CDL is a unique product that provides annual updates of the agricultural landscape. The entire inventory of CDL products is available for download from the Geospatial Data Gateway.

"ArcGIS Desktop [software] from ESRI makes it possible for us to create resourceful maps to identify the spatial extent and associated acreage of the crops grown in these specific states," said Mueller.



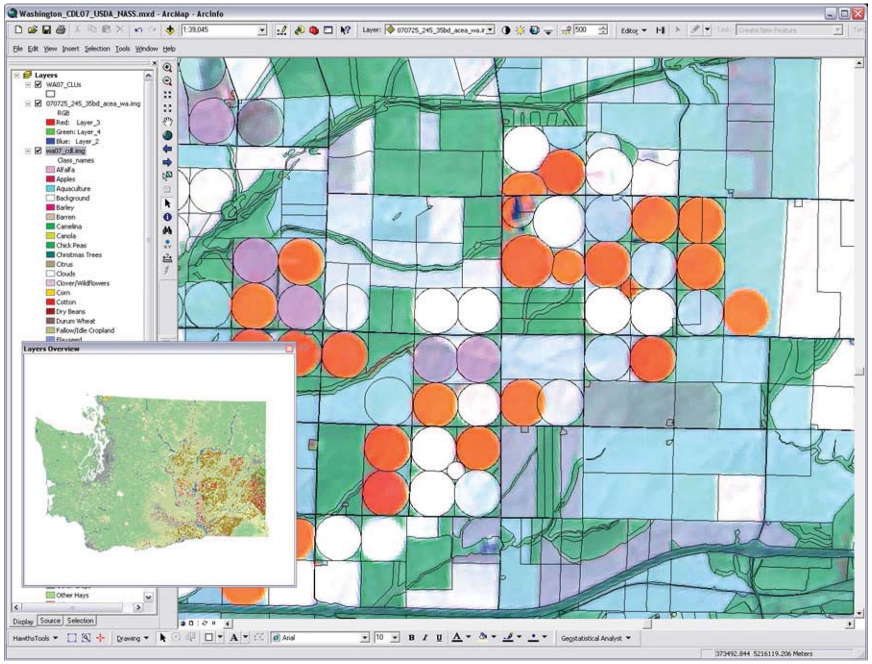
A combination of the Washington 2007 Cropland Data Layer with raw AWiFS data taken on July 25, 2007, shown with Common Land Unit overlay using the swipe function. The band combination displayed is 3,4,2.

ESRI's ArcMap application is also used to create finished products—detailed, informative maps of U.S. cropland for agricultural stakeholders. GIS specialists use ArcMap to create maps that are distributed to NASS field offices, where they are used at trade shows and distributed to customers. ArcMap is also used to create the CDL Web Atlas, where each county within a state is plotted with the location of acreage planted with corn, oats, winter wheat, peas, and other crops and encapsulated in a single PDF file. The increasing functionality of ESRI's desktop products has enabled the delivery of large-scale geospatial datasets like CDL to desktops.

Each year, the CDL program focuses on highly intensive agricultural regions to produce digital, categorized, georeferenced output products. NASS uses ArcGIS Desktop to manage and edit administrative ground reference data such as the Common Land Unit (CLU) from the USDA/

Farm Service Agency. The CLU data is a survey-based record of where specific crops are grown. That information is combined with satellite-based remote-sensing imagery to produce supervised classifications of each field within the state. Satellite imagery is provided by the Resourcesat-1 Advanced Wide Field Sensor (AWiFS), launched in 2003 by the India Space Research Organization.

The CDL program was created in 1997 as an offshoot of the NASS Acreage Estimation Program, established to sync satellite images with farmer-reported surveys. Research and development have been ongoing since the mid-1970s to deliver real-time estimates of acreage at the state and county levels using remote-sensing science. Acreage estimates are used for legislation and government programs pertaining to agriculture. The CDL program is producing real-time acreage estimates over the Midwest and Mississippi River Delta areas for crop year 2008 and delivering a unique geospatial product to the GIS and remote-sensing user community.



A raw AWiFS image dated July 25, 2007, is shown with Common Land Unit data overlay. The band combination displayed is 3,4,2.

For more information or to download the Cropland Data Layer, visit www.nass.usda.gov/research/Cropland/SARS1a.htm. For more information about GIS for agriculture, visit www.esri.com/industries/agriculture.

(Reprinted from the September 2008 issue of *ArcWatch* magazine)

Better Crop Estimates in South Africa

Integrating GIS with other business systems

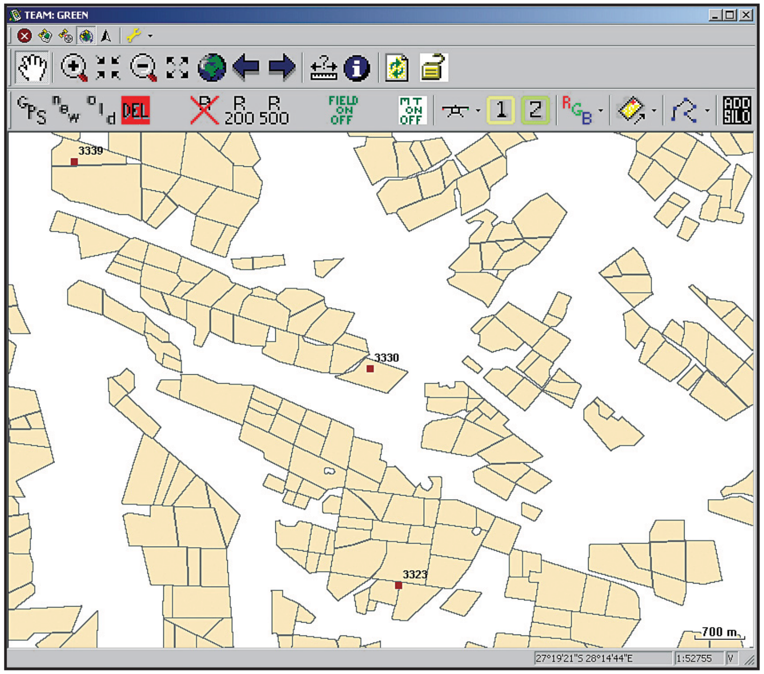
By Annalie Fourie, GIS Specialist, SiQ

Summary

Reliable crop information is vital to the functioning of grain markets. It is used to inform decisions on planting, marketing, and policy. Applying GIS to the process of preparing crop estimates has improved accuracy while lowering costs.

More accurate and reliable crop estimates help reduce uncertainty in the grain industry. The South African Department of Agriculture Crop Estimates Committee was tasked with producing crop estimates for South Africa on a monthly basis. To perform this task, the committee receives data from various input suppliers.

SiQ, a member of the National Crop Statistics Consortium (NCSC), uses statistical methods to provide inputs to the committee. Since 2002, crop information provided by producers has been used for statistical analysis. However, problems caused by producers who don't provide complete information, combined with a greater emphasis on improving statistical accuracy and efficiency, led to the development of an alternative system.



The ArcPad interface used for data capturing in the field. The red squares indicate the randomly selected sample points displayed on a background of digitized crop field boundaries.

The Producer Independent Crop Estimate System (PICES) was developed in 2005. Implemented after a successful pilot study conducted in the Gauteng province, PICES uses crop field boundaries digitized from satellite imagery with a point frame sampling system to objectively estimate the area planted with grain crops.

The PICES process consists of the following steps:

1. Obtain satellite imagery.
2. Digitize crop field boundaries from satellite imagery.
3. Design the point frame and select random sample point.
4. Use aerial survey sample points to capture crop data.
5. Perform statistical analysis.

Obtaining Satellite Imagery

Satellite imagery for the project is made available by the South African government through the Department of Agriculture. SPOT Image Spot 5 satellite imagery with a 2.5-meter resolution is obtained from the department and is used as the base layer for digitizing.

Digitizing Crop Field Boundaries from the Satellite Imagery

This is done in ArcMap at a scale of 1:10,000. Comprehensive quality control measures are part of the digitizing process to ensure clean, accurate data of high quality. Detailed metadata is captured in ArcCatalog as soon as the dataset for a province has been finalized. This metadata is updated whenever changes are made to the dataset. All nine provinces of South Africa have been digitized—a total of approximately 12,965,000 hectares. The updating schedule and procedures ensure that the dataset remains current.

Designing the Point Frame and Selecting Random Sample Points

In the next step, sample points are randomly selected to represent potential cropped fields. These points will be surveyed in the field. A point grid of 45 meters by 45 meters is set up for the total provincial area. Grid points located outside field boundaries are removed from the sample population because these points are unlikely to locate crops.

Digitized fields are stratified based on the probability of finding a crop. The core strata used are high, medium, and low cultivation. High, medium, and low refer to the densities of fields within any given area as well as the presence of pivot irrigation and small-scale farming. Stratification is done to increase sampling efficiency. More sample points are used in strata where there is a higher likelihood of finding crops of interest. This will obtain the most useful data within budget constraints and keep the Coefficient of Variance (CV) as low as possible. *[CV is the ratio of standard deviation to the mean; it is used when comparing datasets with different units or widely differing means.]*

An example of digitized crop field boundaries and the SPOT Image Spot 5 satellite imagery used for digitizing the boundaries.

The grid points are selected per stratum and exported to a Microsoft SQL Server database. These points are sorted systematically from west to east and north to south. This is done to ensure an optimal geographic distribution of sample points. A random starting point is chosen and points selected at regular intervals according to the number of points needed in the specific stratum. The selected points are inserted into a new table in the database, and the process is repeated for each stratum. Finally, the SQL Server tables are added in ArcMap and converted to shapefiles containing the sample points for each stratum.

Aerial Surveying of Sample Points to Capture Crop Data

An aerial survey of the sample points is conducted. This aerial survey determines which crop is planted in the field represented by each sample point. These surveys are conducted by a field observation team that consists of a pilot and an observer in a very light aircraft. The observer is from the agricultural community and is very experienced at distinguishing between different crops and differentiating between dry land and irrigated cultivation. Typically, the number of sample points verified for each survey requires the use of more than one field observation team. This system of capturing field information for crop estimate purposes is believed to be unique in the world.

A section of the 45-meter by 45-meter point grid after the removal of grid points outside the crop field boundaries. Crop field boundaries stratification is also shown.

A Tablet PC connected to a GPS and running ArcPad is used to capture this data. ArcPad is customized with a user-friendly interface. The field observer notes which crop is planted at the sample point and whether it is dry land or irrigated cultivation. Additional information, such as growth problems or areas of double-cropping, is also captured. In addition to the data that is being captured, the observer also takes photos to provide more information on the conditions in the field during the specific survey. Each photo taken is automatically linked to a shapefile that indicates where it was taken.

Performing Statistical Analysis

The field data is captured and stored in shapefile format. This data is uploaded to a central server on a daily basis and imported into a SQL Server database. Expansion statistics are used to calculate estimates of the area planted in each grain crop on a provincial basis.

Conclusion

The need to objectively estimate area planted under grain crops prompted the development of PICES. The system uses crop field boundaries digitized from satellite imagery together with a point frame sampling methodology and aerial field surveys to objectively estimate the area planted for each grain crop. PICES has proved to be extremely cost effective when compared with the previous system that used information gathered from producers. An area of approximately 12 million hectares can be covered in a two-month period using three field observation teams. The accuracy has also been improved by 40 percent per province. The use of GIS has greatly improved crop estimates in South Africa and resulted in more cost-effective, accurate, and objective grain area estimates.

About the Author

Annalie Fourie is a GIS specialist for SiQ. She obtained her honours degree in GIS from the University of Pretoria, South Africa. She obtained her bachelor's degree in town and regional planning from the same university. Since 1999, she has been involved in diverse GIS projects.

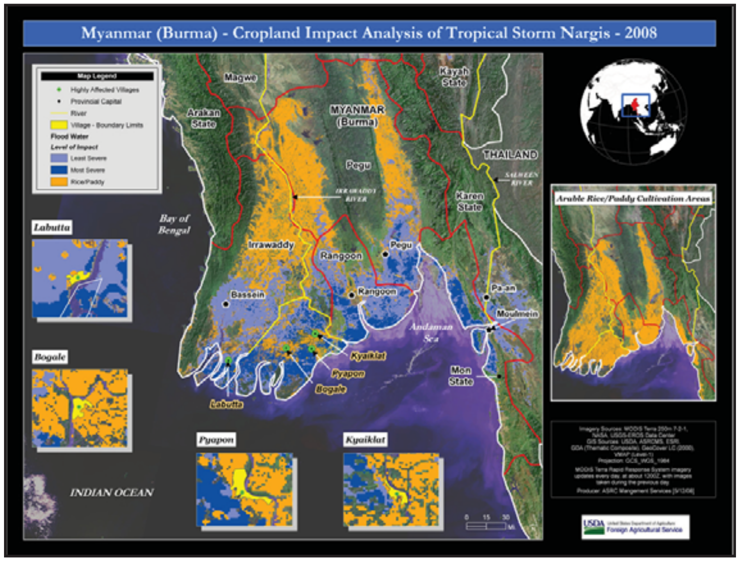
(Reprinted from the Winter 2009 issue of *ArcUser* magazine)

Cyclone Nargis Leaves Its Mark on the Map

Analyzing and Monitoring Myanmar's Damaged Rice Production Regions with GIS

By Matt Freeman, ESRI writer

With 132-mile-per-hour winds, Cyclone Nargis, a category 3 tropical storm, struck the low-lying and heavily populated Myanmar coastline on May 2, 2008. The intense storm produced a 12-foot sea wave that flooded an approximate 2,000-square-mile area, home to 24 million people. More than 90,000 people died and 56,000 people went missing in the country once known as Burma.



Data from the MODIS and Landsat satellites allow the FAS to produce a map of the cyclone-damaged rice production regions of Myanmar.

Adding to the tragedy of the lives lost, the cyclone destroyed much of Myanmar's agricultural economy in the inundated areas. The provinces of Ayeyardwady, Yangon, Bago, and Mon, which account for 58 percent of the country's rice crop, or roughly 6.2 million tons on a milled basis, were inundated with saltwater from the flood. In addition to the cropland damage, many villages were destroyed along with much of the villagers' food stocks, livestock, and farming supplies.

After the storm, the Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA) produced a series of commodity intelligence reports focusing on the country's damaged agricultural areas. FAS uses remote-sensing and geographic information system (GIS) software to analyze global crop production capacity, then issues commodity intelligence reports to reveal international crop conditions. These reports contain maps created with geospatial data and the technology found in ESRI's ArcGIS software. Published on the FAS Web site, commodity intelligence reports and GIS-based maps help improve foreign market access to American agricultural products, build new markets, improve the competitive position of U.S. agriculture in the global marketplace, and provide food aid and technical assistance to foreign countries.

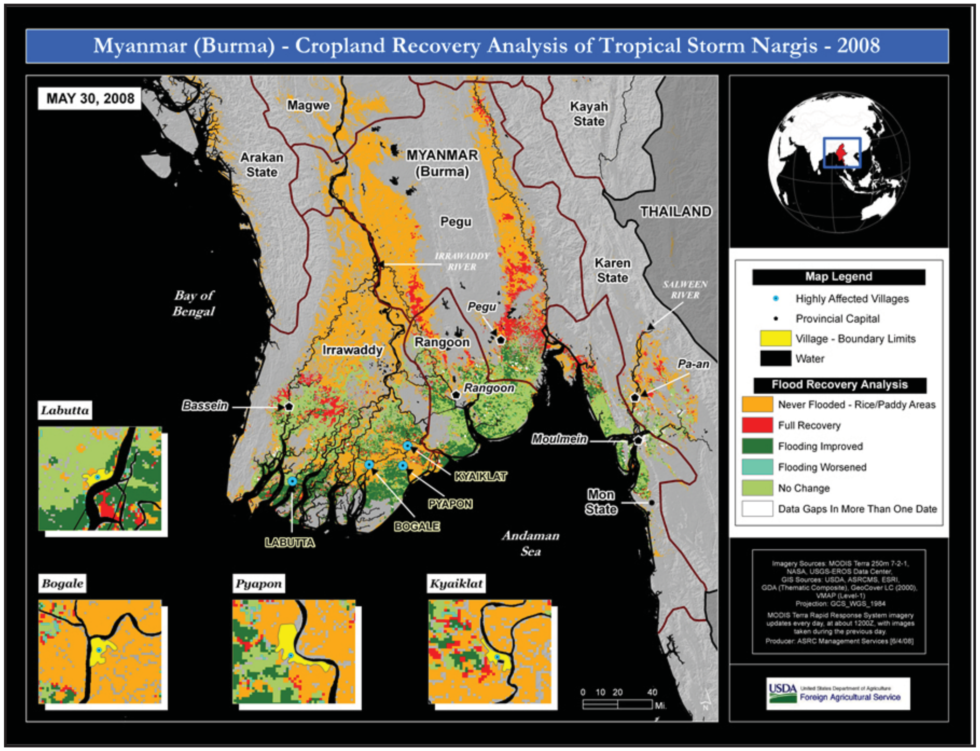
In the case of Cyclone Nargis, the reports also provide the agriculture industry with a detailed perspective of where remediation efforts need to be conducted before the country can begin to produce a normal rice harvest. See the May 15, 2008, Commodity Intelligence report.

The maps that support FAS commodity intelligence reports include data from various sources. For example, satellite imagery obtained from the National Aeronautics and Space Administration's (NASA) moderate-resolution imaging spectroradiometer (MODIS) satellite delineates the post-cyclone flooding region. Combined with rice land-cover classification data from the Landsat satellite program and the tools in ArcGIS software, maps of the damaged rice production regions of Myanmar are easily created. These FAS-produced maps reveal the cyclone's effect on cropland and livestock, the severity of flooding, and the rate of cropland recovery. The United Nations (UN), nongovernmental organizations (NGOs), and the international agriculture industry have also used these resources to evaluate the scope of the cyclone's impact.

GIS Reveals the Areas Damaged by Saltwater

Due to restrictions imposed by the Burmese military, relief efforts were slow after Cyclone Nargis and little could be done to aid in the recovery of Myanmar's flooded rice croplands, much less ensure a normal harvest. Saltwater is a serious problem for rice cultivation, and Myanmar's inundated fields would need to be drained and flushed with sufficient freshwater before normal cultivation could be considered and normal crop yields could occur. Drainage became a problem even in areas where few farmers perished because the rice fields are designed to store rainfall as freshwater irrigation. Not only did the cyclone destroy lives and property, it crippled the storm-affected regions' agricultural economy.

"Our GIS maps and flood classification data show that the areas originally inundated by the storm account for approximately 1.7 million hectares of rice, 24 percent of the national rice area, or roughly 2.5 million tons of rice production on a milled basis," says FAS international crop assessment analyst Michael Shean. "The core region most severely damaged by the tidal wave and high winds, however, accounted for approximately 900,000 hectares of rice land, 13 percent of the national rice area, and roughly 1.35 million tons of milled rice production. In addition, field reports from inside the affected region indicate that within these rice production areas, large numbers of villages were destroyed along with much of their food stocks, livestock, and farming supplies."



A GIS map created 28 days after Cyclone Nargis passed through Mayanmar shows the progress of the country's cropland recovery efforts.

In a second FAS commodity intelligence report, issued June 10, 2008, GIS maps showed that approximately 80 percent of the original inundated rice production area was still affected by some degree of flooding. Fortunately, at that time, conditions in the core damage zone had improved considerably, with only 418,000 hectares, or 46 percent of the original area, still showing flood damage.

The June 10 report also stated that Myanmar's heavy rainfall season was approaching and that it was unknown whether the rain itself would provide sufficient aid in diluting the salt levels in inundated fields or in flushing saltwater from affected soils. In the meantime, the Myanmar government began seeking financial aid to acquire 6,000 tons of salt-tolerant rice seeds to sow approximately 100,000 hectares of rice in areas with the worst saline conditions. According to FAS map data, however, this still amounts to only 6 percent of the inundated region.

Assessing Livestock Using GIS

In the farmable areas, the grim tasks of determining how many people died and relocating survivors and livestock continues. A lack of accurate assessments on the ground about basic needs such as food, shelter, drinking water, and farm supplies have made it difficult for FAS or the UN to determine the actual capacity of recovered farming villages and their abilities to cultivate a normal rice crop. Fortunately, livestock source data provided by the UN's Food and Agriculture Organization (FAO) is available. FAS used it to author the Cyclone Nargis Livestock Impact Analysis and GIS map. FAO data indicates that most rice farmers in Myanmar own two water buffalo or cattle to carry out their normal farm operations. Scientists estimate that nearly 200,000 cattle were killed in the storm. The FAS map is useful for prioritizing areas where donated cattle or even gas-powered farming equipment are most needed.

Post-Cyclone Nargis GIS maps of Myanmar generated by FAS have proven so valuable in monitoring the flood recovery in Myanmar that the agency has received requests from many organizations for customized maps. "Our maps and data layers are available on a case-by-case basis," says Shean. "We have recently been contacted by a couple of UN groups that are interested in our Myanmar flood analysis layers."

As conditions change and new data becomes available, FAS will continue to produce its own GIS maps, perform analysis, and issue commodity intelligence reports focused on Myanmar's rice production regions. For more information about FAS Commodity Intelligence Reports for Myanmar, visit www.fas.usda.gov.

(Reprinted from the December 2008 issue of *ArcWatch* magazine)

Purdue University Students Visualize Soils and Landscapes with GIS

Highlights

- Desktop and mobile GIS is used to study the relationships between soils, topography, land use, and geology.
- GIS integrates soil and landscape data from various sources.
- Newly released data, map products, and models continue to advance.

Understanding how soils form in the field and vary across landscapes is a critical skill for today's agronomists; therefore, it is an integral component of the curricula at Purdue University in Indiana. Students use GIS in the classroom and in the field to better understand soils and landscapes and to recognize geologic features that indicate different soil types.

Soil Classification, Genesis, and Survey, a class cotaught by professors Darrell G. Schulze and Phillip R. Owens, incorporates the latest GIS software to study the relationships between soils, topography, land use, and geology. The teachers use GIS to share data with the students, who in turn use it to observe different points in the landscape. At the beginning of the class, most students know little about geography and GIS, but by the time they complete the course, they are able to access geographic data and view it with GIS tools.

In addition to using GIS in the classroom, students from Purdue University study soils and landscapes while on the go using Mobile GIS on Tablet PCs.

Schulze accesses the United States Department of Agriculture (USDA) soil survey data, as well as data from the Indiana Spatial Data Portal and the Indiana Geological Survey. "This data is robust," notes Schulze. "In 2007, USDA completed digitization of soil data for Indiana, so I can access soil data for any county in the state." Schulze takes on the task of downloading this data, along with high-quality aerial photography and high-resolution digital elevation models (DEMs). Using GIS to aggregate the data in various ways that fit class objectives, he creates a variety of useful data files. For example, he created a dominant soil parent material model that groups polygons together so that students can see relationships not readily apparent from traditional representations of soil survey data.

Longtime users of ArcGIS, Schulze and Owens have their students visualize the geomorphology of their study area with GIS. "Students easily relate to the features they can see while they are standing in a field; however, larger landscape features that occur over kilometers are much more difficult to immediately understand," explains Owens. "Teaching soil geomorphology using Tablet PCs and GIS provides the students with tools to see patterns over large distances and has revolutionized our ability to teach spatial relationships."

Students can see, for instance, that Purdue is located in a part of the world that was glaciated 20,000 years ago and understand close correlations between the soil parent material and the surficial geology. DEMs highlight relevant topographic variations. By comparing this with soil data, students make conjectures about how geologic phenomena have affected soils. They can see, for example, that soils formed on dense glacial till that was smeared down and compacted by the ice as the glacier moved along its path are wet because the water cannot move readily through the dense material. Sandy and gravelly soils that formed on the outwash that was deposited by the rapidly running water from the melt are better drained, and they do not have a high water table in the winter like the soils on glacial till. GIS shows how the difference in the internal soil drainage class of those soils is influenced by the different parent soil materials.

By projecting the desktop onto a screen, the teacher demonstrates GIS operations in the classroom. Students become familiar with basic viewing features, such as zoom in and pan and toggling layers on and off, as they begin to review datasets and relationships.

Professors at Purdue University incorporate the latest GIS technology to share data with students.

During the normal weekly three-hour lab periods, the class goes on short, local field trips near campus. Students take along assigned ruggedized Tablet PCs, which are loaded with ArcGIS Desktop and integrated with GPS, as they drive to locations near campus. There, they examine soil pits to study soil types.

Later in the semester, there are two all-day field trips. Students travel by bus from West Lafayette, Indiana, north to Lake Michigan on the first trip and as far south as Bloomington, Indiana, on the second. Class time is continued while traveling on the bus, and students are literally oriented as they follow their routes via the GPS and ArcGIS interface on their Tablet PCs. The bus has a monitor on which the teacher continues to teach soil-to-geology relationships.

Students can explore the lesson and make observations on their Tablet PCs. "While we are traveling to our destination, I use GIS to display the outcome on a monitor mounted in the bus," says Schulze. "We can show them how to read the landscape. They learn that a slope or a particular shape of a hill was formed by a particular geomorphic process and can then deduce the material that is underneath. They learn to recognize, for instance, an esker, which is a long, skinny hill that has sand and gravel under it where there was once water flowing under the ice. Using their Tablet PCs, they can compare the virtual esker with the reality of the landscape.

GPS indicates, in real time, where they are on the map, verifying their interpretation of what they are seeing. Using these tools in the field makes topics much clearer than trying to understand the material from a textbook, where these connections are more abstract."

Purdue is located in Tippecanoe County. In the western half of the county, a lot of the soils have been formed under prairie vegetation, giving them dark-colored surfaces. In the eastern half of the county, soils formed under forest vegetation and have a lighter color. The prairie soils tend to be slightly better for growing crops because they are higher in organic matter and, overall, the topsoil has better physical properties. Forested soils are more prone to crusting. This type of soil identification can help agronomists predict yield. These delineations are made obvious to students out in the field who can make map to reality comparisons.

Newly released data, map products, and models continue to advance with each new class. Schulze is currently working on an application in which students can click a polygon to query the attribute table as well as click a link that leads them to a schematic diagram of a soil profile that illustrates what the soil looks like below the surface.

"Two approaches can be taken in using GIS for education," explains Schulze. "One is teaching about GIS and how it works, and the other is using GIS to teach particular concepts. In the latter, teachers design maps for students, working them into a format that works well for the specific class. The data is preassembled and put into a format that works easily for the student and helps the teacher focus precisely on the topic. Hands-on use of GIS-loaded Tablet PCs reinforces concepts from the lecture. GIS is helping us teach concepts in our class that would otherwise take students years of field experience to acquire."

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

In China, GIS-Based Land Registry Aims to Protect Farming Rights and Enhance Food Security

By Peter Rabley, ILS, and Elton Yuen, ESRI Canada Limited

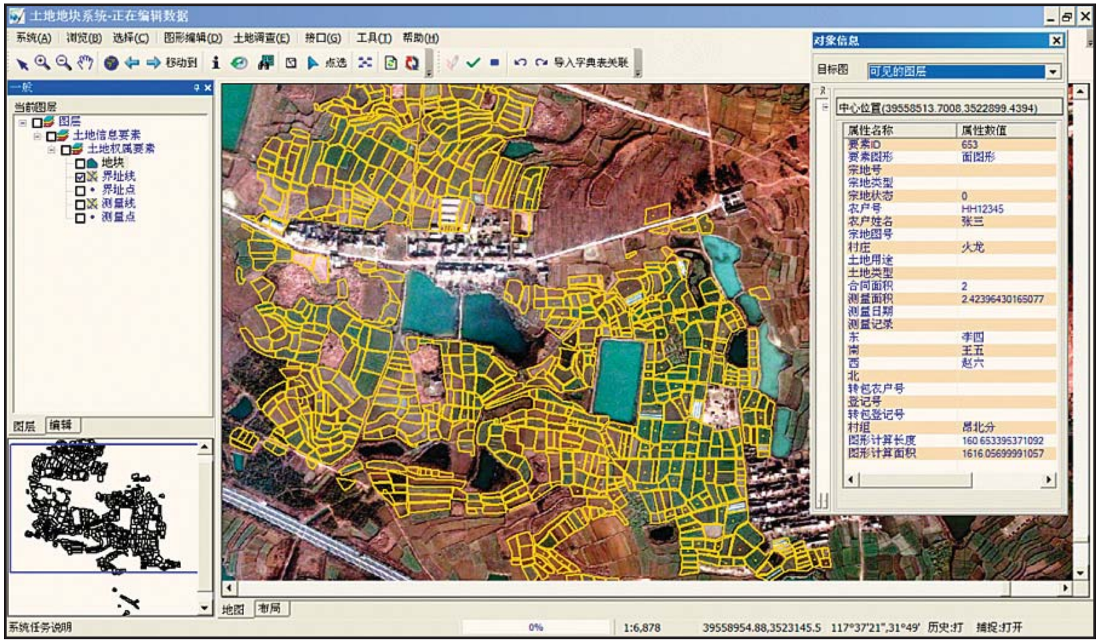
Highlights

- The cadastral data management system is used to build and store parcels, survey points and lines, and cadastral maps and reports.
- The land registry software accommodates the local laws, as well as Chinese language and documentation.
- With a GPS rover unit used as a base station, the 25-centimeter accuracy desired for the pilot was achieved.

This article is part three of a multipart series focusing on GIS-based land and title registry.

International Land Systems (ILS), Inc., an ESRI Business Partner in Silver Spring, Maryland, teamed with Landstar Digital Technology, Beijing, China, and ESRI Canada Limited (ESRI's distributor in Canada), Toronto, to demonstrate the feasibility of applying state-of-the-art GIS and surveying technologies to solve one of the most pressing land policy challenges facing China today. Results of the recently completed field pilot may ultimately serve as the foundation for a nationwide GIS-based rural land registration and certification program that will enhance China's ability to feed its people by safeguarding the land rights of its 800 million farmers.

In many countries, food security, farmers' rights, and land registration are inherently related due to the fact that populations are growing while the acreage of arable land is not. In China, agricultural land areas may even be shrinking as local governments at the collective level in rural areas are enticed by opportunities to convert the collective-owned arable lands for development and other purposes. (There are approximately 1.5 billion arable land parcels in rural China.)



Landstar Cadastral Data Management System with ArcGIS.

The central Government of China (GOC) understands that once arable land is converted from farming to another use, it is probably lost forever as a source of agricultural production. To make matters worse, for every land parcel removed from agriculture, a family loses its livelihood and joins the ranks of the rural poor.

To protect arable lands and foster sustainable agricultural practices, China has adopted policies and laws aimed at strengthening the land rights of individual farmers. Nearly all arable rural lands are owned by collectives and leased to the farmers by the local collective in contractual lease arrangements that sometimes date back decades. When land disputes arise, it is difficult or impossible for farmers to prove what rights they have to specific pieces of property without adequate documentation.

As a result, China established the Rural Land Registration and Certification Pilot Program through its Agricultural University with funding from the United Nations Food and Agriculture Organization (FAO) and World Bank. The objective of this program is to explore and test legal, technical, and organizational solutions for sustainable rural land registration and certification. The long-term goal of the program is to register every rural land parcel and document its correct boundaries and to formally recognize the land tenure of every farming household in the nation. Implementation of a land registration system capable of achieving these objectives will provide a cascading series of benefits across China.

For the individual farmer, there will be an enhanced sense of security in the knowledge that parcels he cultivates are protected should ownership or boundary disagreements occur. At the collective level, local officials will have access to accurate landownership records as they make decisions that impact land rights. And just as importantly, the central government will have more accurate rural land-use data at its disposal as it plans and carries out a variety of administrative policies to combat poverty and enhance food security.

Commitment to Land Tenure

The commitment to sustainable land registration comes from the highest levels of China's central government, the People's Party. The Rural Land Registration and Certification Pilot Program grew directly from 2005 collaboration between the World Bank and the China Development Research Centre of State Council to devise action plans related to the nation's land reform policies. The World Bank in principle agreed to fund future downstream implementation of a land registration system, assuming its technical feasibility could be demonstrated in a field pilot.

At the request of GOC in 2006, a team was assembled to test the legal, technical, and organizational aspects of developing a GIS-based rural land registration system in China. This team included international and local partners with a long history of providing GIS consulting services and land registration systems worldwide. The team also sought and received additional funding for the pilot from the Canadian International Development Agency.

Partners, such as ILS, were selected because they have successfully implemented their cadastral-focused land titling systems in countries around the world using ILS' Land Registry System (LRS), an off-the-shelf suite of applications created specifically to bring modern real property title registration where little or none existed in the past. The project team relied on the LRS system to develop specific workflows and business rules, which would be used to customize the LRS software. The software would then be able to accurately manage the process of registering landownership deeds and agricultural leases and awarding relevant certificates to the owners and leaseholders.

Feidong County Project Management Office assisting farmers in registration applications.

Landstar Digital Technology developed a cadastral data management system (CDMS) with ArcGIS software to serve as the GIS mapping solution for the pilot. The CDMS is used to build and store parcels, survey points and lines, and cadastral maps and reports. The Enterprise Services Group (ESG) International of team member ESRI Canada was instrumental in acting as the systems integrator for this project and was able to quickly configure the LRS land registry software to accommodate local laws, Chinese language, and documentation, as well as provide integration with the land survey and other spatial data from the Landstar system. Specifically, a Web services interface was developed between the LRS and CDMS systems so that land registry documents and historical data could be accessed by clicking on an individual parcel in the map. A unique identification number was assigned to each parcel survey in the pilot. This ID number is the link between the CDMS maps and the LRS.

Stakeholders in the project, including representatives from the Chinese government, evaluated several areas before deciding the pilot would take place in the Anhui Province. Ultimately, they selected two villages—Angbeifen and Longsan—in Shitang Township of Feidong County. Together, these two very small villages contain 89 farming households with rights to work approximately 800 parcels of land. Due to continual subdividing of land for distribution within families, a single agricultural parcel in this pilot area is often less than a mu (one mu equals 1/15 of a hectare, or 666 m^2) in size.

Preparation for the pilot included a review of the policies, laws, and procedures that would govern the registration and certification process for rural lands. As part of earlier land policy reform activities, FAO had assisted GOC in writing a Land Registration Manual with similar guidelines pertaining to urban land registration. Project participants spent considerable time modifying these existing documents to create a legal framework that could apply to rural lands.

Pilot participants gathered available mapping data (provided by the Chinese Ministry of Land and Resources) to load into the CDMS. Already existing were 1:10,000-scale aerial photos, a land-use/land-cover "patch" map created from the aerial photos, and a landownership map of the villages. The ownership map depicted village borders and agricultural lands but did not contain boundaries of individual parcels. A 60-centimeter-resolution QuickBird satellite image was purchased from DigitalGlobe as an additional basemap.

The Pilot Begins

The Feidong County government established a project management office (PMO) and equipped it with a desktop computer running the land registration system (LRS and CDMS), a high-quality printer, and a laptop computer. Trimble China outfitted the PMO survey team with a Trimble S6 GPS Total Station, two Trimble R8 rover GPS units, and other equipment, and ESRI provided software required to conduct survey-grade parcel mapping.

The first step in the pilot included a visit to the village where the farmers were eager to learn more about land registration and its benefit to them. Many had been issued certificates years before by the Chinese Ministry of Agriculture, which were supposed to demonstrate the farmers' contractual rights to work in specific fields. But in the absence of surveying and mapping techniques at the time of issuance, most certificates lacked proper identification of field locations and boundaries.

Next, the pilot participants explored the parcels that would have to be mapped and viewed the small sizes of most fields as a surveying challenge. On the positive side, the majority of fields were bordered by visible boundaries, such as streams, roads, and footpaths. Given the size of the parcels, the team determined that field surveys would have to be performed to an accuracy of 25 to 30 centimeters.

The data collection phase of the pilot began in the county PMO where a land registration form was printed from LRS. A team of trained county personnel took one form to each farmer and helped the farmer fill it in with details about himself, his family, lease agreements, parcels, and crops. If the farmer had additional documents relating to his contract, the team collected them for scanning into the land registry.

As this occurred, a mapping team took the Trimble GPS equipment and surveyed the farmer's fields. In some cases, the boundaries were surveyed, while in others, just the corner points were captured. Neighbors were called in to agree on boundaries that were not clearly delineated.

With one of the GPS rover units used as a base station, the crews usually achieved the 25-centimeter accuracy desired for the pilot. The surveys often took an entire day because fields worked by an individual farmer are typically noncontiguous and located throughout the countryside surrounding the village.

For the sake of comparison, a second mapping team later visited the fields with the laptop computer and attempted to digitally sketch the boundaries of each parcel on the village map underlain by the QuickBird satellite image. Although the satellite image did not have sufficient resolution to meet the desired 25-centimeter accuracy, this method proved to be a fast and efficient technique for creating parcel maps for the majority of parcels because their borders were often so well defined by paths or other visible features. When there was no physical boundary, the boundaries were surveyed.

The Project Management Office survey team outfitted with Trimble survey equipment at the pilot area.

After each interview and survey was completed, staff at the Feidong County PMO loaded the information into the land registration system. They also entered details from the questionnaire into the system and scanned related paper documents. The field surveys were downloaded from the GPS units and laptop into the GIS portion of the registry package. Technicians created accurate parcels and gradually populated the village basemap with the boundaries of every parcel under contract to a farmer.

The pilot team printed completed parcel maps and returned to the villages where the farmer and his neighbors reviewed the work. Upon agreement by all interested parties, the parcel map was signed by them and scanned back into the land registry system as an official survey document. If the documentation relating to the farmer and his land contract was also completed, the system printed an official certificate identifying that farmer, the terms of his rights to the land, and legal descriptions of the parcels he farmed.

Pilot Recap

The pilot spanned approximately three months in fall 2008. Then project stakeholders examined the results and culled lessons from the endeavor. A national rollout strategy report is under development. The overall reaction from all involved has been very favorable. Among those aspects of the pilot that may be modified if the project is expanded is the use of GPS to survey the boundaries of every field. Given the excellent visual delineation of parcels, it may be more cost-effective to capture boundaries with high-resolution orthorectified image data and rely on GPS to locate corner points.

The experiences and lessons gathered from this pilot project are important to formulating recommendations for a national rollout strategy, but they are not nearly enough in their own right to provide the information the Government of China needs to ensure sustainable land registration throughout the country. Given the enormous differences in, and scale of, land issues within China, it is important that the next phase conduct a series of larger-scale pilot projects at different locations within China so that various hypotheses can be tested and appropriate solutions developed. These would include a series of legal, institutional, technical, and financial measures that could create a framework from which a national system can be developed.

It will also be important for the government to decide on the appropriate institutional home for registration from which it can prepare the needed human resource base; define regulations and procedures; and establish funding mechanisms, including possible revenue generation to ensure sustainability. China may consider initially rolling out the registration program in coastal or peri-urban regions where land transfers are relatively frequent and land values relatively high.

Finally, a sustainable land registration system means not only that it must be financially viable in the long term but that it must also contain no financial, legal, or time disincentives to the farmers themselves to enter and continue to use the system. This means that farmers must also be educated, through far-reaching public awareness programs, about the benefits to them to register their land. This will ensure that the system will continue to capture all subsequent transactions and will reflect a complete and transparent record of land transactions. However, there should be no underestimating the enormous task that lies ahead for China and its people.

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