Eye on the Farm

Used to monitor crop conditions in Iraq, new remote sensing processes help predict the agricultural outlook in countries where the food supply is a key political issue.

By Kevin P. Corbley

Just weeks into the 2007-08 growing season, the Iraq Ministry of Agriculture knew that wheat and small grain farms were in trouble in the country's normally plentiful northern region. Signs of an impending drought, which eventually affected much of the Fertile Crescent, had been detected early enough for Iraqi government officials to avert a famine by arranging for food shipments to the impacted areas.

Early warning of the drought in Iraq was the successful result of a pilot project conducted jointly by the National Geospatial-Intelligence Agency (NGA) and the U.S. Department of Agriculture Foreign Agricultural Service (USDA FAS). The goal of the pilot was to develop new remote sensing processes for assessing crop health and predicting harvest yields in growing regions where minimal information is available regarding actual conditions on the ground.

"FAS is the primary source of foreign crop production information that is vetted and published in USDA's comprehensive forecast of supply and demand for U.S. and global crops," said Brad Doorn, director of the USDA International Production Assessment Division.

From an economic perspective, this information is critical in establishing worldwide prices for agricultural commodities such as wheat, oilseeds, rice and cotton. On a more humanitarian front, as was the case in Iraq, these forecasts enable aid organizations to pinpoint potential disruptions in the food supply so that relief can be sent before people begin to starve.

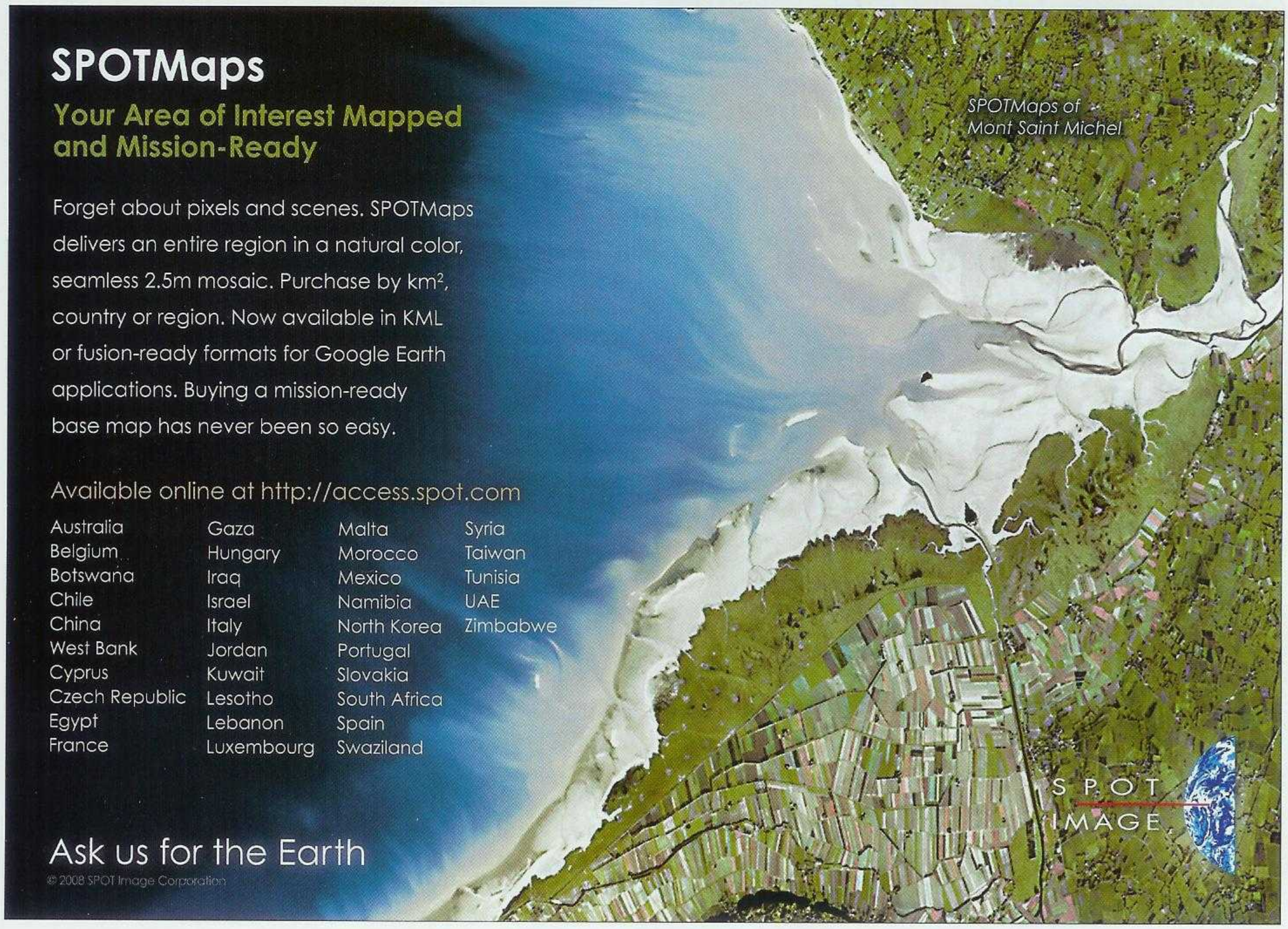
The technology demonstrated by the project is also valuable from a security perspective, because ability to stabilize a food supply is a major component in keeping a nation secure. As economic pressures have continued to grow from globalization, population pressures, resource depletion and global warming, the demand for global crop intelligence products has risen dramatically over the past few years.

Doorn explained that FAS typically makes its forecasts based on the convergence of evidence methodology using enormous volumes of information, including medium- and low-resolution multispectral satellite imagery as well as meteorological data. But Doorn is quick to add that this remotely sensed information is supplemented by extensive observations and reports from trained observers located throughout the growing regions being monitored.

"[In Iraq] we had very limited reporting out in the fields because that infrastructure doesn't exist," said Doorn.

Although human observations on the ground can never be replaced entirely, a primary objective of the pilot was to determine if the high-resolution satellite imagery often used by NGA for intelligence purposes could be integrated into existing FAS processing methodologies. Participants in the pilot accurately predicted that an analysis process combining high-, mid- and low-resolution multispectral satellite data could help to fill information gaps in parts of the world where ground-based observations do not exist.

"The uniqueness of the process [developed in the pilot] is the multi-resolution look at agriculture conditions," said Bob Tetrault, archive manager of the USDA FAS Satellite Imagery Archive.



Multispectral Analysis

For most international assessments, USDA FAS relies on medium-resolution imagery from the Indian AWiFS sensor and low-resolution data from the NASA MODIS, SPOT-Vegetation or NOAA AVHRR sensors. Used in the Iraq pilot, the MODIS sensor (Moderate Resolution Imaging Spectroradiometer) collects imagery covering entire regions in a single pass at spatial resolutions ranging from 250 meters to a kilometer in up to 36 multispectral bands. It flies on two different NASA satellites providing daily global coverage, and is processed and delivered through the global agriculture monitoring partnership between USDA FAS and NASA.

When assessing growing conditions, MODIS performs double duty. As a meteorological tool, the satellite reveals cloud formations across large regions, enabling analysts to determine how much precipitation has fallen on a particular area. For agricultural forecasting, MODIS imagery of the land surface can be processed to extract indices that measure moisture and chlorophyll in vegetation.

While it's impossible to identify crops or cultivated fields with 250-meter resolution, these MODIS indices offer insights into whether drought conditions exist over a large area. Comparison of MODIS indices from the 2007-08 Iraqi growing season against a NASA archive showed the Middle East region had much lower moisture and biomass than normal this season, the first indication that rainfall had not been as plentiful as in past years.

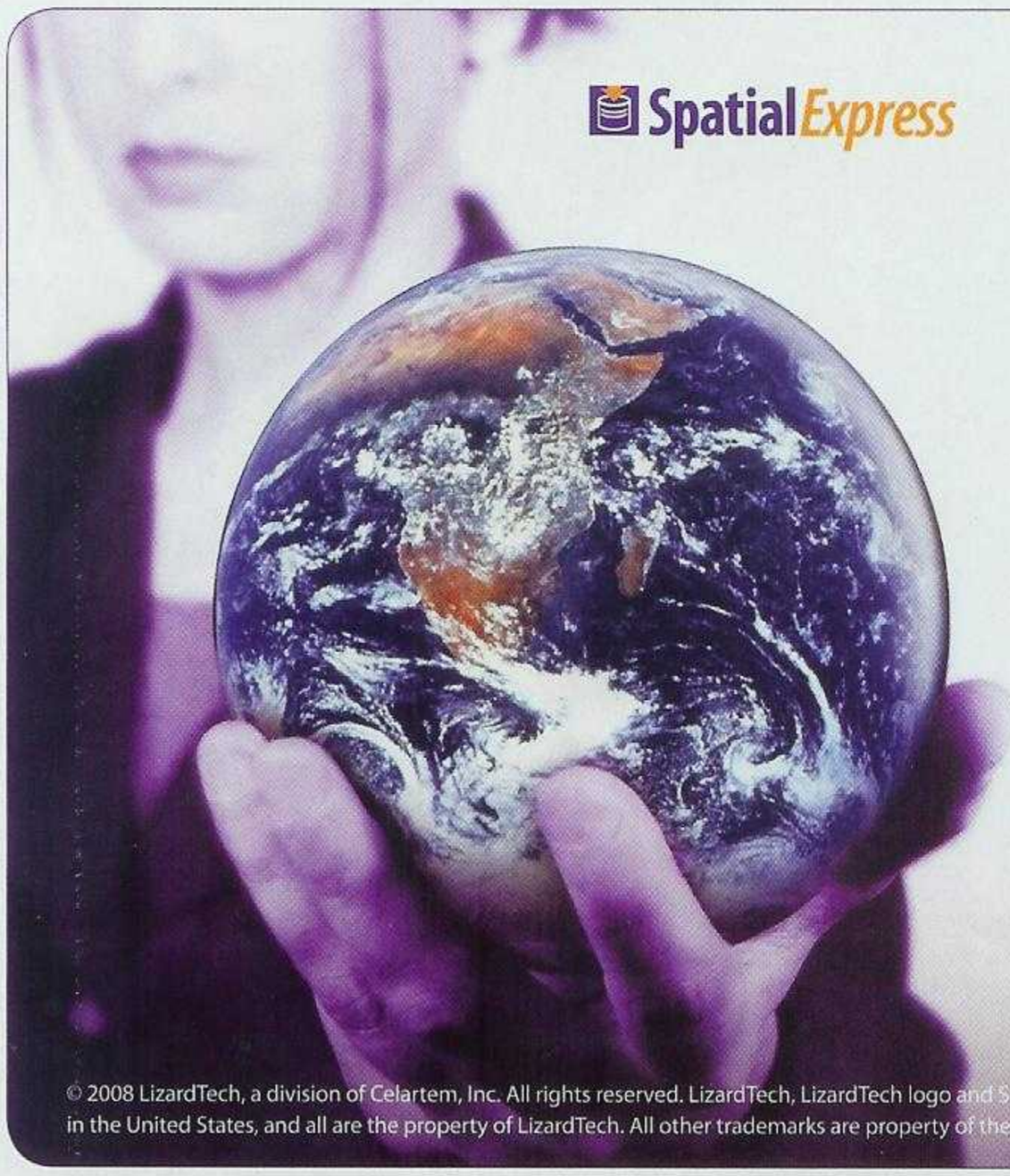
With the lower-than-normal rainfall suspected, the analysts turned to AWiFS aboard the Indian Resourcesat-1 satellite with its medium 56-meter spatial resolution and 740-kilometer-wide swath. USDA began using this Indian data, which is supplied by ASRC Management Services (ASRC MS), three years ago in all of its assessment projects as a replacement for the ailing Landsat satellite. AWiFS resolution is sufficient to identify farming areas, and its multispectral bands and frequent five-day revisit make the sensor ideal for monitoring nationwide agricultural conditions.

"Frequent revisit is critical in identifying certain types of crops and determining their relative health," said Sean Griffin, an ASRC MS remote sensing crop analyst who provided image processing support to the Iraq pilot.

The spatial resolution of the AWiFS imagery enabled the analysts to pinpoint known wheat and grain producing areas in Northern Iraq. Vegetative health indices derived from these images confirmed the biomass growth was well below that of previous years. The large swath of the sensor covered much of the nation, giving the remote sensing researchers the ability to compare and contrast the effects of the drought conditions in farm fields across Iraq.

"The advantage of the medium-resolution was that we get frequent countrywide images at farm level," said Doorn.

At this point in the process, USDA analysts normally would have turned to their ground-based sources to quantify the drought impact by field and crop type. But in the pilot, they instead requested NGA to obtain commercial high-resolution satellite imagery of 18 farm locations in Northern Iraq. Utilizing an existing acquisition contract with DigitalGlobe, NGA supplied multispectral QuickBird imagery with 2.5-meter



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spatial resolution captured at five different times during the growing season.

The high-resolution multispectral imagery provided details about each field. The imagery differentiated wheat from other crops and revealed whether farmers were actively working the fields and irrigating them. The condition of crops that had flowered could be quantified as well. In a few fields, there was no sign of any crop at all, indicating that either nothing had grown or the farmer had not planted due to lack of water.

USDA combined QuickBird and AWiFS images acquired at about the same time to create a sequence showing the crop growth—or lack of it—over time. The analysts wanted to use the spectral values of wheat fields in the high-resolution imagery to identify wheat fields elsewhere throughout the medium-resolution imagery to make a nationwide assessment.

The analysts discovered, however, that it was difficult to extrapolate spectral values across an image covering such a wide area as the AWiFS does. Variations in atmospheric conditions from one side of the scene to the other created distortions in spectral values. This problem was solved by GDA Corp., a USDA subcontractor, which developed a standard atmospheric surface reflectance (SASR) technique to normalize the atmospheric interference and make it possible to correlate pixel values from the QuickBird imagery across the entire AWiFS scene.

The SASR process improved the ability to map farm fields and monitor their conditions in Iraq using the AWiFS and QuickBird imagery. Unfortunately, the news was not good. By the time that many crops should have flowered, the number of fields containing healthy wheat and other grains was well below normal. The impact of the drought was confirmed by mid-season, and the information was provided to NGA, which disseminated it to officials in Iraq to arrange for wheat purchases from other countries.

Refining the Process

Project participants consider the multi-resolution imaging pilot a success. With the Middle East drought persisting, NGA has given the green light to continue the efforts in Iraq into the 2008-09 growing season with expanded activities focusing on growing regions in the southern part of the country. The next phase will include the same combination of high-, medium- and low-resolution multispectral satellite imagery.

According to USDA's Tetrault, project analysts have continued to refine the process and will introduce an innovative new way to create cloud-free mosaics of Iraq. A satellite mosaic of a large country or region is made by digitally stitching together multiple images to provide a single snap-shot view of the entire area. GDA has developed a technique to clip out cloud-covered pixels from one scene and replace them with cloudless pixels from another, generating what appears to be a cloud-free mosaic without disrupting information content.

But while a cloud-free mosaic is pleasing to the eye, it can introduce errors in image interpretation. The presence of pixels taken from multiple imagery acquired on different dates can confuse agricultural and other time-sensitive analysis routines, especially change detection. To eliminate this problem, GeoMarc digital watermarking software from GCS Research is being used.

Designed for security purposes, this software embeds acquisition date and other metadata into every pixel. This information stays with the pixels even if they are integrated into another image, making it possible for remote sensing analysts to take into account acquisition dates of individual pixels within a larger mosaic during interpretation. This mosaicking technique is expected to facilitate nationwide crop condition assessments in projects like the one in Iraq.

With the multi-resolution analysis technique proven and several innovations developed in the pilot, USDA's Doorn expects to see the process rolled out for agricultural analysis in other parts of the world where trained ground observers are not available.

"There are a lot of countries like that, and many of them have food security issues," said Doorn. "These projects are made possible by our unique partnering relationship with NGA and our contractors who manage the USDA FAS Prime Vendor Contract."

The USDA FAS Prime Vendor Contract is managed by ASRC MS and Global Marketing Insights. These organizations make sure data product vendors provide the licensing and data sharing regulations needed by the USDA FAS to obtain imagery and final data products quickly and cost effectively from commercial vendors. The contract promotes vendor efficiency in terms of pricing and delivery times. ★

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