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Web-Based System Delivers Near Real-Time Remote Sensing Data

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The U.S. Northern Great Plains is one of the world's most agriculturally productive areas. The region's growers are eager to adopt modern technology to improve productivity and income, so the use of information derived from remote sensing satellites to better manage farms and rangelands has gained popularity in recent years. But prohibitive costs and nonavailability of near real-time remote sensing imagery has slowed the technology's adoption for in-field decision making.

Digital Northern Great Plains (DNGP), a Web-based remote sensing data dissemination system available at http://dngp.umac.org, was developed to address these drawbacks. The system provides users easy, free access to a variety of imagery and products in near real time (see “What's Inside the Digital Northern Great Plains System,” page 30). By delivering archived and current data, DNGP has helped farmers and ranchers reduce operational costs and increase productivity through a variety of innovative applications. Moreover, the system has reduced negative environmental impacts.

Using the DNGP System
Since DNGP's initial release in 2004, the remotely sensed images hosted in the system have provided services to a broad community, ranging from K-12 teachers to government agencies. However, most of the imagery has been used for agricultural management. A farmer or rancher is able to use DNGP to define an area of interest, usually his or her own farm or ranch, and to download all the remote sensing data and products available for that area of interest. DNGP's developer, the Upper Midwest Aerospace Consortium (UMAC), a consortium of seven U.S. universities, has collected a rich archive of remote sensing imagery over North and South Dakota, Minnesota, Montana, Wyoming and Idaho spanning more than 30 years. The Landsat Thematic Mapper (TM) image at the bottom left shows a farm field in Minnesota for which a list of images covering the area at various times was generated automatically for display and download. The archive of past data serves as a reference against which the current status of farms or ranches from near real-time data can be compared.

Typical farming applications include zoning for applying variable rate fertilizer, identifying areas of poor growth, assessing damage for insurance adjustments, assessing and improving drainage conditions, and making purchasing decisions based on land quality. Typical ranching applications include identifying and controlling invasive weeds, estimating livestock carrying capacity and managing wildlife. The following examples show how farmers and ranchers who used remote sensing data downloaded from DNGP were able to analyze their situations and reduce costs.

Zoning Fields and Applying Nitrogen Credits
A typical farm field in the Upper Midwest is 100-150 acres in size, making remote sensing an ideal tool.
for studying in-field variation. Because productivity is impacted by soil, nutrient levels, moisture content, topography and other factors, precision farmers integrate as many of these parameters as they have measurements for into maps defining zones within their fields. After carefully zoning a field based on these factors, soil samples are taken to determine the amount of fertilizer each zone requires.

Closely related to zone mapping is the need to determine nitrogen credits. When sugar beets are harvested, only the sugar-laden root is removed, leaving the biomass of above-ground canopy in the field. The leftover leaves and stems decompose, releasing nitrogen back to the soil. Remotely sensed Normalized Difference Vegetation Index (NDVI) imagery permits site-specific estimates of the above-ground biomass from which one can calculate nitrogen credits. When applying fertilizers for the next crop, farmers subtract these credits from the amount of fertilizer estimated initially.

A farmer in Minnesota’s Red River Valley downloaded the Landsat TM-derived NDVI product from DNGP at the peak growth stage of sugar beets and used it to create zones to estimate site-specific nitrogen credits. Then he carried out soil testing to determine the amount of nitrogen already available. As shown in the image above, the field had larger nitrogen credits where NDVI was higher (dark green). Less fertilizer had to be applied in those zones for the following year’s crop. The farmer reported saving $12 per acre and a total of $1,800 for the entire field through the use of imagery-derived products. Over four years, planting 1,010 acres of sugar beets, the farmer was able to reduce nitrogen fertilizer by 60 pounds per acre on average, saving more than $51,000.

**Assessing Hail Damage**

Hail-damaged crops are common in the Upper Midwest. A farmer in Crookston, Minn., used Landsat TM imagery available from DNGP to delineate areas of wheat, sugar beets and soybeans that were destroyed by a hail storm. As shown in the image below, standard false-color composite imagery reveals a hail storm’s path.

Darker shades of red indicate undamaged wheat, lighter shades of red or pink indicate hail-damaged areas. These variations within the mature wheat fields, coupled with field verifications, allowed the farmer to accurately estimate crop-damaged areas, enabling a quick, uncontested settlement with the insurance company. Besides standard false-color composite imagery, NDVI maps often are used by farmers to determine crop damage. The extent of any damage is defined by comparing an NDVI map obtained before the damage with one obtained shortly after.

**Assessing Water Damage**

The Red River Valley in North Dakota and Minnesota often experiences flooding and waterlogging due to its flatness and sluggish drainage. Farmers use drainage ditches and tile drainage methods to drain water out of their farms so crops can be grown. Some fields in low-lying areas are chronically waterlogged, making drainage ineffective or expensive.

During one growing season, when 10 inches of rain fell in 6 hours, several fields were “drowned out,” destroying the crops. Because the fields became too wet to access, farmers used satellite imagery to identify the affected fields and to map the spatial extent of the damage for insurance claims. One farmer searched DNGP and found a Landsat TM image acquired shortly after the event. As shown in the image below, the waterlogged fields were identified easily as light blue areas in a standard false-color composite image, and the extent of damage was quantified accurately. The farmer also downloaded from DNGP Landsat images from previous years taken during major rainfall events. By combining historical images with ground elevation data using SST toolbox software from SST Software (www.sstsoftware.com), he was able to identify chronically waterlogged fields. This information was used in leasing land for future operations and in planning drainage requirements.

**Detecting and Controlling Weeds in Rangelands**

Knowledge about grass quantity and location within a ranch is important for managing livestock grazing on rangelands. Grass is harvested for winter feed and grazed directly by livestock throughout the growing season. It’s in a rancher’s best interest to monitor grass growth to move cattle accordingly to prevent overgrazing and track weed infestations. Ranchers who download imagery from DNGP routinely monitor forage production throughout the season to decide on stocking rates and when to buy/sell grass for winter feed according to market prices.

On one occasion, a rancher in Montana detected healthy vegetation on late-season imagery when he expected the grass to have senesced already. On ground inspection, the healthy vegetation was determined to be buckbrush and wildrose weeds. The left-hand image on page 30 shows a late summer 2001 IKONOS standard false-color composite (bands 4, 3, and 2) image.
What's Inside the Digital Northern Great Plains System?

The Upper Midwest Aerospace Consortium (UMAC) designed the Digital Northern Great Plains (DNGP) system with a thin-client architecture to ensure the minimum footprint on a client computer; all computing and analyses are carried out by the host server, and results are presented through a Web interface.

Data include medium-resolution (20–250 meters) multispectral images from sensors such as Landsat's Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+); NASA's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Moderate Resolution Imaging Spectroradiometer (MODIS); surface relief from the Shuttle Radar Topography Mission (SRTM); and high-resolution (1–2 meters) images from AeroCam, a multispectral airborne camera developed and operated by UMAC. To ensure consistency in temporal and spatial comparisons, all images are georeferenced and atmospherically corrected using ATCOR software from Satellite Imaging Corp. (www.satimagingcorp.com).

All images are stored in a storage server and managed through an Oracle database system with a spatial operation extension. Although Oracle allows users to store binary data such as images in the database, DNGP's developers chose to store images as external GeoTIFF files and to link the images to the database through their regular and spatial attributes. This approach minimizes the database's size and hence the cost of managing it.

The DNGP system has several features that enable users with low-bandwidth Internet connections to search and download remote sensing data and products easily and quickly. These features include an intuitive user interface that allows users to conduct searches via spatial coordinates, capability to subset remote sensing images either spatially or spectrally, and compatibility with a wide range of application software.

Prior to the development of the DNGP system, FTP and postal mail were the primary ways to deliver imagery, and the coverage of images requested amounted to only about 14 percent of the total UMAC region. Since its initial release in 2004, the DNGP system has enabled more and more agricultural producers to apply remote sensing technology in practice. The total areas of interest have expanded steadily from less than 20 percent of the total UMAC area before 2005 to more than 50 percent in less than four years.

where the yellow oval highlights the area with concentrated wees. [Note: GeoEye’s IKONOS imagery was made available only on specific cases, and it isn't distributed routinely through DNGP.] The rancher was able to estimate the approximate acreage and percentage of the nonproductive portion of his pasture using ArcView software from ESRI (www.esri.com).

Concerned by the extent of the weed infestation and armed with exact locations of the invasive weeds, the rancher implemented a weed control program in spring of the following year. He purchased an ultralight aircraft and began aerial weed control applications. As shown in the right-hand image above, IKONOS imagery collected in the summer of 2002 after herbicide had been applied shows that the weeds had been largely controlled. The grazing area that was salvaged was about 25 acres worth $200 each, for a total benefit worth about $5,000. The following summer,

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the rancher applied weed control over a larger area of 200 acres and recovered land worth $40,000 for grazing. In subsequent years, he was able to use Landsat imagery to monitor his ranch and neighboring ranches.

Ongoing Development

As these examples demonstrate, remotely sensed imagery can greatly benefit agricultural operations. With the DNGP system, users not only have access to satellite and aerial imagery in near real time, but also to georeferenced and atmospherically corrected imagery. As a result, farmers and ranchers use remote sensing images from planning to scheduling for harvest, from mapping nutrient availability to delineating weeds, from identifying standing water to claiming storm damage. In the meantime, the system continues to evolve. The ultimate goal is to transform DNGP from a standalone delivery system to a data delivery backbone driving various decision support systems.

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