Crop Management with Information from Digital Satellite Imagery

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Introduction

Innovators and early adopters of new and emerging technologies involved in farming provided a surge of interest in production agriculture due to considerable media coverage. While the word revolution implies a sudden or complete change, the use of information technologies in horticultural crop production has been somewhat of a slower evolution as innovators searched for practical applications for farm management. As a suite of technologies became available, a new strategy that combined information with decision-making became known as precision agriculture (National Research Council, 1997). This concept has also been referred to as site-specific crop management. High-resolution satellite imagery from digital sensors provides information for analysis and interpretation of crop growth and offers valuable in-season progress reports. Fierce competition and strict confidentiality are expected in fresh market vegetable crop production. While possession of information may infer more knowledge, the real power of information lies in knowing how to use it to manage more effectively. Satellite imagery offers an ability to extend the vision of what can be seen by humans and provides end-users with an opportunity to acquire visual information that can be used in crop management. Numerous practical applications of remote sensing technology for crop management of high value fruits and vegetables, including fertility and water management, have been previously identified (LeBoeuf, 2000).

Technology Shift from Public Sector to Private Sector

The Land Remote Sensing Policy Act of 1992 brought about significant changes as applicants from the private sector were allowed to obtain licenses to operate in satellite technology (KMPG Peat Marwick LLP, 1998). This action prompted a quick surge of interest in 1993 as remote sensors were evaluated on aerial platforms in the San Joaquin Valley in California. It was also in 1993 that the global positioning system (GPS) became fully operational with 24 h a day coverage providing latitude, longitude, elevation, and time of day information (National Research Council, 1995). Interest in satellite technology was also shifted from the public sector into the private sector with the 1994 Presidential Directive by President William Clinton when he decided to allow commercial companies to acquire and market one-meter spatial resolution imagery. Applicants from the private sector were allowed to obtain licenses to operate satellites through the United States Department of Commerce. By 1994, numerous foreign countries such as India, France, Russia and Japan had started to create medium to high spatial resolution imagery for commercial use.

Low Spatial Resolution Satellites

Prior to the development of high-resolution imagery, low or coarse resolution satellite imagery of 10 to 30-m spatial resolution offered a look at in-field crop situations. The use of 10-m (32.8-ft) resolution imagery provided nine times more pixels than 30-m (98.4-ft) resolution imagery which is typical of U.S. Landsat imagery (Verbyla, 1995). SPOT (Le Systeme Pour l'Observation de la Terre) satellite imagery operated by the French Space Agency has 10-m panchromatic imagery along with 20-m (65.6-ft) color imagery. SPOT Image (Reston, VA) markets imagery from the SPOT-4 satellite, which was launched in 1998 and expects to handle imagery from SPOT-5, which is scheduled for launch in 2002. SPOT-4 does not have a blue band (450 to 520 nm) so true color images are not available. True color images are made up by combining the three additive primary colors of blue, green (520 to 600 nm), and red (630 to 690 nm) bands, which make up the visible range of the electromagnetic spectrum. False color images are made from near infrared (760 to 900 nm), red, and green bands. Information on the satellite constellation operated by SPOT can be found at: http://www.spot.com.

All of the coarse spatial resolution satellites offer 8-bit digital data that corresponds to 256 levels of gray scale (2 to the 8th power) which allows for image classification from 0-255.

High Spatial Resolution Satellites

The first successful launch by a United States private sector company of a high-resolution satellite was achieved by Space Imaging (Thornton, CO) on September 24th, 1999. Their IKONOS (Greek word that means picture) satellite offers 1-m (3.28-ft) spatial resolution imagery in panchromatic (black and white) and 4-m (13.1-ft) resolution in multi-spectral color (blue, green, red, and infrared). The IKONOS satellite is in orbit at an altitude of 680-km (Gerlach, 2002). The global connection for satellite imagery can be seen by the team of investors involved with IKONOS satellites: Lockheed Martin Corporation, Raytheon, Inc., Mitsubishi Corporation, Singapore's Van Der Horst Ltd., Korea's Hyundai Space & Aircraft, Europe's Remote Sensing Affiliates, the Swedish Space Corporation, and Thailand's Loxley Public Company Ltd. Information on the satellite constellation operated by Space Imaging can be found at: http://www.spaceimaging.com. DigitalGlobe (Longmont, CO) operates the world's highest spatial resolution satellite. DigitalGlobe was formerly known as EarthWatch, which was a merger between EarthWatch Incorporated, Ball Aerospace, and WorldView. DigitalGlobe's QuickBird satellite was successfully launched on October 18, 2001. QuickBird offers 61-cm (2-ft) resolution at nadir (looking straight down from the satellite) in panchromatic and 2.44-m (8-ft) in multispectral color. DigitalGlobe operates the QuickBird satellite in a sun-synchronous orbit of 450-km around Earth that is significantly lower than that of the IKONOS satellite, thereby achieving higher spatial resolution (Lindgren, 2001). Key investors of DigitalGlobe include Ball Aerospace, Hitachi Ltd., ITT Industries, Inc. and Morgan Stanley Dean Witter. QuickBird imagery is expected to be available for commercial use in spring of 2002 depending on national security issues due to the terrorist's attack on America in September of 2001. As soon as QuickBird was successfully launched, Space Imaging lowered their prices for high-resolution satellite imagery. So competition has helped cut the costs of imagery to end-users. Information on the satellite constellation operated by:
DigitalGlobe can be found at: http://digitalglobe.com.

Both IKONOS and QuickBird satellites offer 11-bit digital data that corresponds to 2,048 levels of gray scale (2 to the 11th power) which allows for image classification in areas such as shadows for more powerful image enhancement compared to the 8-bit data from other satellite systems. This is what is meant by the term higher radiometric resolution.

A network of authorized resellers of satellite imagery is in place to help end-users in selecting the appropriate imagery and they can be found listed in the web sites of the satellite companies. Some network partners such as AgriDataSensing of Fresno, CA offer value-added services such as spectral analysis of original data files for the various sensors along with image classification.

Mapping Accuracy Standards

There are numerous satellite products available for use in crop management, which should be matched up with the end-user's applications. Horizontal accuracy statistics may be shown as 12-m CE90 which would mean that any point within the satellite image is within 12-m horizontally of its true Earth's position on the surface 90% of the time as CE stands for circular error. Vertical accuracy is usually shown as linear error or LE.

Imagery can also be identified by scale with United States National Map Accuracy Standards (NMAS) such as 1:4800 which means that one cm on the image represents 4800 cm on the ground. It is important to remember that image scale is not the same as spatial resolution as scale is totally independent of the pixel size. It is also important to know what the accuracy standards are when an end-user wishes to stack maps for analysis of different layers of information. Quadrangle maps from the U.S. Geological Survey are usually published with a NMAS statement.

Supervised Classification versus Unsupervised Classification

The difference between supervised and unsupervised classification of digital satellite imagery is basically knowing the different cover types that will be used in the classification before the analysis is performed. An unsupervised classification requires no knowledge of the grouping of pixels into classes. The use of a histogram to look at the range of pixel values can be an indicator of spectral signatures when crops are known in the image, especially if the fields are of large acreage. Spectral analysis can be performed with upper-end computer software packages such as geographic information systems (GIS). Individual pixel values can be identified for the various sensors and crop identification can be achieved with adequate ground truthing to verify what is in the field compared to what is being identified in the image. The higher the image resolution, the more data there is to classify and identify, process, and store in databases. Ground truthing is also important when a crop is under attack from insects, plant disease, or subjected to competition from weed species.

Raw Data Sets versus Pretty Pictures

When imagery is acquired with the digital data files, statistical analyses can be performed to extract valuable information for crop management. This type of analysis requires image processing software and upper end computer hardware. Time is involved in the data analysis but potential information relevant to crop production and weed management makes the effort worth a lot more than just getting a pretty picture from a technology provider. Areas with extensive weed pressure can change the reflectance characteristics of a crop. Mapping of perennial weed species such as *Convolvulus arvensis* L (field bindweed) has been used by the author to direct spot treatments with ground applications of glyphosate (Roundup) instead of sending a tractor across a large field looking for areas to be treated with the herbicide. Perennial weeds typically grow in concentrated areas and management efforts can be targeted to spots identified in digital imagery. This has been seen with *Cyperus esculentus* L.(yellow nutsedge) which appears in sandy, light soils. Digital imagery combined with GIS and GPS equipment allows for specific mapping that also aids in site-specific weed management of annual weeds such as *Avena fatua* (wild oats) (Hanson et al., 1995).

Crop Management and Decision-Making

Recent developments in technology have shown that the cornerstone to successful farming is information. Innovative producers are often looking for a competitive advantage when they choose to use new visual information based technologies such as satellite imagery. The use of digital imagery in high value vegetable crops in California has been beneficial when ground truthing activities were performed to verify what was depicted. Satellite sensors provide information about crop health and identify plant stress. Imagery provides for effective crop monitoring if timely processing, analysis, and delivery is achieved. Ground truthing enhances diagnosis and meaningful information can then be applied to a management response that is site-specific. The examples identified from horticultural production in California have the potential to be applied to other commodities in various growing regions. As site-specific weed management becomes adapted in other crop production regions, the decision making process used by farmers and ranch managers will be enhanced. Numerous other benefits of satellite imagery will ultimately be discovered.

Literature cited

Gerlach, F. 2002. "Orbitology" - The High and the Low of It. Imaging Notes. Vol.17, No.1. p6.

Hanson, L.D., P.C. Robert, and M. Bauer. 1995. Mapping wild oat infestations using digital imagery for site-specific management, p.495-503. In: P.C. Robert, R.H. Rust, and W.E. Larson (eds.). Site-specific management for agricultural systems. Amer. Soc. Agron., Madison, WI.

KPMG Peat Marwick LLP. 1998. The satellite remote sensing industry: A global review. Space and High Technology Practice, Arlington, VA..

LeBoeuf, J.B. 2000. Practical applications of remote sensing technology - an industry perspective. HortTechnology. Vol.10, No. 3. p.475-480.

Lindgren, J. 2001. Getting a grip on large images. Imaging Notes. Vol.16, No. 6. p. 24-25.

National Research Council. 1995. The global positioning system. A shared national asset. Committee on the Future of the Global Positioning System and Commission on Engineering and Technical Systems. National Acad. Press, Wash., D.C.

National Research Council. 1997. Precision agriculture in the 21st century: Geospatial and information technologies in crop management. Committee on Assessing Crop Yield - Site-Specific Farming, Information Systems, and Research Opportunities. National Acad. Press, Wash., D.C.

Verbyla, D.L. 1995. Satellite remote sensing of natural resources. Lewis Publishers, Boca Raton, FL.