THE NEXT ERA OF LAND REMOTE SENSING FROM SPACE: IMPLICATIONS FOR CRANBERRY GROWERS

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Background

Several interrelated factors are influencing the form and significance of "the next era" of land-oriented satellite remote sensing systems, all of which have also impacted on agricultural management in the US. Among these are:

- continued transition toward an information-based society in general;
- recognition of the interdependence between environmental quality and sustainable economic development; and
- the continued maturation and application of kindred geospatial technologies such as geographic information systems (GIS) and the Global Positioning System (GPS).

As a consequence of the above, spatial technologies are playing an increasingly central role in land and natural resource management activities, the conduct of business and government, and the advancement of scientific knowledge about the earth as a system. As applied to agriculture, widespread application is presently practiced or is being considered in crop acreage estimates, crop disease detection, weed and insect infestation, and off-farm effects on surrounding lands (Robert 1997.)

With the coming of the next generation of satellites, and vast improvements in computational infrastructure at every level, remote sensing promises a new set of innovative tools for small and large farm operations alike. With those promises, however, come important caveats which must be considered by all prospective users. The purpose of this paper is to give an optimistic sense of the "next era", balanced with technical and economic trade-offs that all potential remote sensing data users, including those in agriculture, should consider before committing to remote sensing technologies.

Remote Sensing is a Technology That Is Large, Diverse, and Here to Stay

We are entering an era of tremendous growth in the development and application of geospatial technologies in general, and satellite remote sensing in particular. With the relaxation of military intelligence constraints in the civil marketplace, at least four US

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companies or consortia are either operating, or planning to operate, advanced capability imaging systems, as are international private sector and government consortia. Value added data and service providers, including those specifically designed for the agricultural industry, are becoming more numerous as the latent commercial demand for their products continue to be realized. The specifications of the four major U.S. high resolution commercial systems launched or planned for launch by the year 2000, summarized on Table 1, gives an indication of the magnitude of investment and technology development in this area.

Table 1. Preliminary Specifications for U.S. Commercial Satellite Remote Sensing Systems Planned for Launch by 2000

Source	*Satellite Name*	*Expected Launch*	*Spectral Bands*	*Wavelength (μm)*	*Resolution at Nadir (m)*	*Swath Width at Nadir (km)*	*Revisit Time (days)*
EarthWatch	**EarlyBird**	**launched**	**G**	.490-.600	15	15	2-5
		12-24-97	R	.615-.670	15	15	
			NIR	.790-.875	15	15	
			PAN	.445-.650	3	3	
	QuickBird	1998	B	.450-.520	3.28	22	1-4
			G	.520-.600	3.28	22	
			R	.630-.690	3.28	22	
			NIR	.760-.900	3.28	22	
			PAN	.450-.900	0.82	22	
ORBIMAGE	**OrbView-**	1998	B	.450-.520	4	8	2-3
			G	.520-.600	4	8	
			R	.630-.690	4	8	
			NIR	.760-.900	4	8	
			PAN	.450-.900	1	8	
			PAN	.450-.900	2	8	
			HYPER*	.450 - 2.5, and 3.0-5.0	8	5	
Resource21	**Resource21**	2000	B	.450-.520	10	205	<1
			G	.520-.600	10	205	
			R	.630-.690	10	205	
			NIR	.775-.900	10	205	
			MIR	1.55-l .65	20	205	
			MIR	1.23-1.53	100	205	
Space Imaging/ EOSAT	**IKONOS**	1998	B	.450-.520	4	11	9-11**
			G	.520-.600	4	11	
			R	.630-.690	4	11	
			NIR	.760-.900	4	11	
			PAN	.450-.900	1	11	

*280 narrow band channels.
**Revisit time substantially less with tilt > 10" .

Primary sources upon which this table is based include the current homepages for the various firms. The information contained above is preliminary and subject to substantial change.

Additionally, some 42 other satellites have been placed in operation since 1990 or are scheduled to be launched by 2004 (ASPRS 1996). Several include non-U.S. systems (e.g., SPOT and the Indian IRS system) with spatial resolution of 10 meters or less. Other optical systems follow in the footsteps of the Landsat system (e.g., wide swath widths, intermediate to low resolution, and relatively broad spectral coverage). A number of the satellites will feature hyperspectral capacity (numerous narrow bandwidths, further discussed below), and still others will feature radar sensor systems. An up-to-date summary and links to additional information on all of these satellite systems is maintained on the ERSC homepage (http://www.ersc.wisc.edu/ersc/resources.html).

Challenges and Considerations for Integrating Remote Sensing into Agricultural Management

The challenge for commercial remote sensing data providers, the agricultural community, university researchers, and others, is to consider what will be the technically and economically appropriate role for remote sensing in the near future. As with any tool available to the agricultural community, there needs to be careful consideration as to whether the investment in same will have the level of expected economic return. Some of the most important considerations, discussed below, include the following: **spatial resolution; swath width; spectral resolution; temporal considerations; data delivery considerations; and finally ultimate usefulness to agricultural management.**

Spatial Resolution - Although the present spatial resolution (e.g., SPOT 10 meter panchromatic) has been satisfactory for the evaluation of many past agricultural operations, precision farming may require a l-5 meter spatial resolution. (Robert 1997). Of the satellites presented above, those proposed by EarthWatch, Orbital Sciences Corporation, and Space Imaging/EOSAT will feature panchromatic imagery available at l-3 meters. A major consideration will be that of data volume. For example, at 1m resolution, a 40 acre field will encompass approximately 162,000 picture elements (pixels); a single acre comprises approximately 4050 pixels! This data volume may necessitate 10’s of gigabytes of storage capacity for a medium sized farm operation.

Swath Width - With the exception of the Resource 21 sensor (swath width = 205 km), the swath width of these systems is relatively narrow (3-22 km). Many farming operations or cooperatives, with wide-spread operations across multiple townships or counties, may consider the extent of coverage a more important consideration than spatial resolution for some applications.

Spectral Resolution - The recent ORBIMAGE announcement that the OrbView- will carry a 280 band hyperspectral sensor offers a new range of challenges and opportunities. Combinations of these narrow bands may allow the development of anomaly detection systems that would detect even very early stages of plant stress or pest infestation. The trade-off again will be data volume (280 data observations per 8 meter pixel).

Temporal Considerations - The stated revisit time of all four satellite systems is less than a week[2]. Chris Johannsen of Purdue University notes that this is the most important

[2] Note the caveat for Space Imaging EOSAT and the revisit time of 9-11 days, with substantially less with a tilt of > 10°.

aspect of remote sensing for agricultural purposes as the frequency of the image coverage is paramount to fast and effective crop management response. Confounding the temporal consideration is the impact of weather (cloud cover) on the ability to obtain usable satellite data at the requisite frequency for agriculture. In anticipation of weather-related complications to satellite data collection, many satellite data providers and users are planning to complement their satellite data acquisition with airborne counterparts and substantial ground-based observations. *Determining the optimal mix of space, airborne, and ground-based observations in the context of a variety of agricultural applications in near-real time will be a great challenge.*

Data Delivery Considerations - A number of the satellite data providers stress their commitment to deliver “products” or “information”, and not raw “data”. Raw data is often minimally corrected for geometric and atmospheric distortions, and needs a certain level of processing to be useful to the end user. Data processing has a price, however, both in terms of final cost and time period between the collection of the data by the satellite and its delivery to the data customer.

Usefulness to Agricultural Management - Past attempts to integrate remote sensing techniques in agricultural management have largely failed due in part to the lack of infrastructure in farming regions to acquire, process, and interpret the data, and then make appropriate agronomic recommendations (Robert 1997). It is critical that farmers and farm cooperatives communicate the usefulness of such information to the data providers and crop consultants, as well as to university researchers and agricultural extension agents. Such information sharing will be critical to advance the state of the art.

Resources at UW-Madison and Beyond

A logical first step in considering geospatial information technologies for those involved in agriculture in Wisconsin is a review of some of the university, state and federal resources available on the internet (Table 2). Many are interactive with sample images and applications, and most provide links to additional information.

Table 2. University, State, and Federal Resources for Remote Sensing

Name	Description	WWW Address
Environmental Remote Sensing Center	UW-Madison facility for interdisciplinary research on the application of remote sensing to environmental monitoring and resource management.	http://www.ersc.wisc.edu/ersc/ (Web site contains documents on research activities and programs, publications, staff, faculty and students profiles as well as links to other web resources devoted to remote sensing)
NASA Visiting Investigator Program	NASA-sponsored program designed to provide U.S. companies a low cost (no exchange of funds) opportunity to examine the application of current and future remote sensing technologies in their businesses	http://www.ersc.wisc.edu/ersc/Projects/VIP/vip.html (Description of the program and current and future VIP projects)
Wisconsin Initiative for Statewide Cooperation on Land Cover Analysis and Data (WISCLAND)	Statewide initiative designed to develop and sustain a long-term partnership among organizations to collect, analyze and distribute statewide land cover and natural resource information	http://www.ersc.wisc.edu/ersc/Projects/WISCLAND/wiscland.html (Project description and links to related resources)

Timely Satellite Data for Agricultural Management (TiSDat)	NASA-sponsored program to facilitate access to satellite data for potential users. Applications include: determining potato irrigation needs and cranberry frost prediction	http://bob.soils.wisc.edu/nasacan.html (Program description and resources)
USGS Global Land Information System (GLIS)	An interactive computer system developed by the U.S. geological Survey (USGS) to assist in finding data about the Earth's resources, including the archive of Landsat Thematic Mapper	http://edcwww.cr.usgs.gov/webglis/
EarthWatch Incorporated	Provider of satellite data, including high spatial resolution commercial imagery.	http://www.digitalglobe.com

Conclusions

Farmers and agribusinesses interested in remote sensing data will be forced to face numerous trade-offs in resolution, revisit period, swath width, and spectral range. Considerations are also numerous relative to the overall accessibility, reliability, timeliness, and mode of delivery of the data to users. Furthermore, the technical integrity of the data (spectral, spatial, and radiometric) and the range of image product options will also be important. All of the above furthermore need to be considered within the cost structure and contractual agreement for the data product.

The issues presented here are but a small portion of the overall international picture of private and governmental systems that are either available or are planned for launch soon. Organizations such as the American Society for Photogrammetry and Remote Sensing (ASPRS), the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Agency (NOAA), and the US Geological Service (USGS), as well as leading land-grant universities are on the forefront of research and applications in remote sensing as applied to agriculture and natural resources. Those interested in learning more about remote sensing in general and satellite remote sensing systems in particular are encouraged to consult the various texts or references available on the subject (e.g., Lillesand and Kiefer, 1994) and/or the numerous relevant publications available through ASPRS.

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