

High-Resolution Satellite Imagery and Resource Management

Urban forest managers in Eagan, Minnesota, like Gregg Hove, have been facing a challenging issue with the city's oak trees for several years now. Oak wilt disease continues to threaten Eagan's urban landscape by destroying one of Minnesota's most valued shade trees.

With no silver bullet solution to thwart its progress, the city relies on fungicides and many preventative tactics to control outbreaks. One critical activity is locating and monitoring oak wilt sites to, at minimum, contain the disease. Typically, this is done by looking at aerial photos and sending out ground crews to verify the problem. But budget and time constraints prevent the city from identifying every oak wilt case.

A half-hour from Eagan in St. Paul, Minnesota, researchers at the University of Minnesota's Remote Sensing and Geospatial Analysis Laboratory (RSL) are testing high-resolution satellite imagery to monitor oak wilt disease. With just a few ground samples, they're using these pictures from space to create maps that could potentially guide users to every oak wilt disease center. Field tests confirmed that oak wilt was correctly identified in 9 out of 10 sites previously unknown to the Eagan Forestry Division.

Researchers at the RSL have acquired and worked with over 50 scenes of commercial high-resolution satellite imagery during the past three years. This fact sheet is a compilation of commonly asked questions regarding the use of high-resolution satellite imagery for natural resource management.

Whether the resource is water, forests, wetlands, urban infrastructure or agricultural crops, resource managers need an aerial perspective to monitor and manage resources. Traditional methods of acquiring geographic data include ground-based inventorying, GPS, aerial photography and moderate-resolution satellite imagery.

Aerial photographs and moderate resolution satellite images have contributed and will continue to contribute invaluable spatial information to natural resource managers, improving their ability to monitor the earth's resources. With spatial resolutions as high as a few inches, aerial photos have provided researchers and managers with the ability to analyze and manage resources at local scales. Since their beginning, these visual tools have become indispensable when a spatial perspective is needed.

With the federal Land Remote Sensing Policy Act of 1992, natural resource managers have yet another option. This act enabled companies to launch high-resolution satellites capable of capturing images with spatial resolutions less than 1 meter. Previously, anything more detailed than 10 meters was restricted to military reconnaissance.

As the name implies, high-resolution satellite data provides spatial data with greater detail.



Figure 1. QuickBird high-resolution satellite orbiting 423 miles above the earth's surface.

It can potentially be used to monitor natural resource conditions that are difficult, even impossible, to detect with traditional monitoring techniques. In addition, it's comparable in detail to aerial photography, easy to integrate into a GIS, available at a reasonable cost and supports multitemporal analyses important to studying changes in natural resources. Following are commonly asked questions regarding this image option.

1. What companies sell commercial high-resolution satellite imagery?

Three companies have been granted licenses to build and operate satellites capable of producing 0.6 to 1-meter resolution data. In September 1999, Space Imaging (www.spaceimaging.com) successfully launched the IKONOS-2 satellite with electronic sensors capturing and transmitting high-resolution images. IKONOS generates multispectral or color images with 4-meter resolution (13.1 feet) and panchromatic or black and white images of 1-meter (3.3 feet) resolution.

In 2001, DigitalGlobe (www.digitalglobe.com) also successfully launched a high-resolution satellite called QuickBird-2 to gather 2.44-meter multispectral images and 0.61-meter panchromatic images. The third company, ORBIMAGE (www.orbimage.com) is scheduled to launch its satellite, OrbView-3, in 2003.

2. How do prices of commercial high-resolution satellite imagery compare to aerial photos?

The price of any remotely sensed image, from an aircraft or satellite, depends on the product (e.g., panchromatic or multispectral), scale, resolution, level of processing, area of interest, rush tasking and whether satellite tasking is required if an archived image is not suitable.

With all of these considerations, comparing prices of high-resolution satellite imagery to aerial photos can be difficult. Table 2 provides a base level comparison of a panchromatic/multispectral product from IKONOS and QuickBird with scanned (non-rectified) and orthorectified aerial photos.

Table 1. Comparison of IKONOS and QuickBird imagery.

	IKONOS	QuickBird
Image Bands	Panchromatic, blue, green, red, near infrared	Panchromatic, blue, green, red, near infrared
Single Scene Coverage	10 x 10 kilometers 6 x 6 miles	16 x 16 kilometers 10 x 10 miles
Revisit Time	3 days	3 days
Radiometric Resolution Options	8-bit or 11-bit	8-bit or 16-bit
Locational Accuracy	Products range from 2.0- to 25.4-meter (CE90%)	Products range from 10.2- to 23-meter (CE90%)
Minimum Collection Area	Depends on product: Geo imagery has minimum collection of 1 scene.	Depends on product: Basic imagery has minimum collection area of 1 scene
Cloud Coverage	All imagery equal or less than 20% cloud coverage	All imagery equal or less than 20% cloud coverage
File Formats	GeoTIFF, NITF 2.0	GeoTIFF, NITF 2.0, NITF 2.1

There are two aspects that can make satellite imagery more cost effective when acquiring smaller geographic coverages (city to township scale). First, film processing and aircraft-related costs are avoided with satellite imagery. Second, aerial photos are often more expensive in the digital, mosaiced and orthorectified formats that are useful to many GIS-based applications. By its very nature, satellite data is in a digital, georeferenced form and therefore GIS-ready.

High-resolution satellites provide imagery that can be collected over a larger geographic area than most aerial photos. For instance, a single IKONOS scene covers 10 x 10 km and QuickBird covers 16 x 16 km. This reduces the need for any mosaicing or edge matching within an area just greater than the size of a

Table 2. Price comparison of aerial photos and high-resolution satellite imagery. Prices are based on a township size area of 121 km² or 46.7 mi².

	Product	Accuracy	Resolution	Product Type	Price Rate
Aerial Photo (scanned, non-rectified)	9-inch	N/A	1-meter	Color	\$4 - 5,000
Aerial Photo (orthorectified)	9-inch	custom	1-meter	Color	\$10 - 15,000
IKONOS	Reference	25-meter	1-meter	Panchromatic & Multispectral	\$5,300
	Precision	4-meter	1-meter	Panchromatic & Multispectral	\$10,000
QuickBird	Standard	23-meter	.61-meter	Panchromatic & Multispectral	\$3,600
	Orthorectified	10 - 12 meter Or custom	.61-meter	Panchromatic & Multispectral	\$7,800

township. These characteristics cut out many hours of image processing.

3. *When would you recommend aerial photos over high-resolution satellite imagery, or vice-versa?*

In our experience, we have determined that high-resolution satellite data is best suited to a local scale analysis which can be contained in a single scene or perhaps narrow north-south oriented study areas. Although the costs of IKONOS and QuickBird images compare favorably to 9-inch metric photographs for a township-size area, aerial photography will cost less for larger areas (e.g., county).

In addition, areas of interest that stretch across counties and regions are not ideal for satellite acquisition due to the restrictions inherent in a north-south orbiting pattern. It can take several passes over several months, which results in a mosaic of phenological differences.

4. *How often could I expect to acquire imagery over the same geographic location?*

The digital sensors of high-resolution satellite imagery allow acquisition of multitemporal sequences, which are important to studying changes in natural resources. With a revisit time of three days, it is possible to collect several acquisitions over the period of a growing season, and georeferenced images from multiple dates may be used for multitemporal analysis.

5. *What does multispectral mean and why is it useful to image analyses?*

Multispectral is an important concept for natural resource managers to understand. It refers to the different portions, or bands, of the electromagnetic spectrum that comprise an image, whether an aerial photo or satellite image.

In contrast to aerial photos, satellite data enable users to select which bands, or combination of bands, to display and use for analysis.

Often, within one company or agency, the imagery needs differ from one department to the next, making it difficult to make one affordable purchase that meets everyone's needs. With aerial photography, users must decide between panchromatic, color or color infrared images. In contrast, the multispectral properties of the satellite imagery allow users to simultaneously have all three of these modes.

The spectral bands in high-resolution satellite imagery systems are also very similar to the first four bands of Landsat and other land-viewing satellites. With proper modifications, many of the applications that have proven successful at a regional scale are possible at local scales with high-resolution multispectral imagery. Some of these applications include:

- Land cover classification
- Forest regeneration surveys
- Lake water clarity mapping
- Impervious surface mapping
- Aquatic vegetation surveys
- Forest health monitoring
- Storm damage mapping

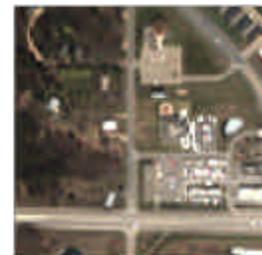
6. *How long does it take to order and acquire commercial high-resolution imagery?*

Often, the company is able to task the satellite within 24 hours of receiving geographic coordinates or a shapefile. On average, users can expect to receive images within three to seven days once the imagery has been successfully acquired, unless they requested additional orthorectification.

It is difficult to predict how quickly satellites can collect cloud-free imagery due to the constantly changing nature of weather. Generally, we have been able to acquire images with less than 10% cloud cover in Minnesota within a one-month time window.

7. *What kind of software is needed to work with satellite imagery?*

High-resolution satellite imagery can be viewed as a backdrop on almost any mainstream GIS software, such as ArcView



a) 4-meter, natural color



b) 1-meter, natural color



c) 4-meter, false color IR



d) 1-meter, false color IR

Figure 2. Examples of IKONOS satellite imagery.

Spatial Analyst/Image Analysis or ArcGIS, which supports TIFF imagery. However, if users want to manipulate, classify or transform the data, they will need higher end image processing software, such as ERDAS Imagine. With this, customers can order the basic, least expensive image product and do some of the

preprocessing themselves. These operations include “layer stacking,” and “resolution merging,” and both operations do not take very long to complete (30 to 60 minutes per image). Users can also orthorectify and re-project the imagery with image processing software.

CASE STUDY: MAPPING CITY LAKE WATER CLARITY

Using moderate resolution Landsat TM satellite imagery and ground monitoring data in a previous study, researchers found that satellite remote sensing is a cost-effective way to gather the information needed for statewide water clarity assessments. Secchi disk transparency, the traditional water clarity measurement, is strongly related to satellite spectral-radiometric observations of lakes.

Recognizing the similarity between the first four multispectral bands of IKONOS and Landsat TM imagery, IKONOS data was applied to assess lake water clarity at a smaller, city scale. They performed the assessment for the City of Eagan, Minnesota, which is particularly well suited for the study since it has 375 small lakes and ponds larger than one acre and a well established lake monitoring program.

Data from the Eagan citizen monitoring group was used to model lake water clarity for all small lakes and ponds in the city. From this model, a map was generated giving viewers the capability to recognize the variability of lake water clarity within and between lakes. Once the final map product was generated, it was overlaid on the original IKONOS data. By doing so, viewers can begin to determine the cause of good and poor lake water clarity through identification of the type of land use and cover surrounding the lakes.

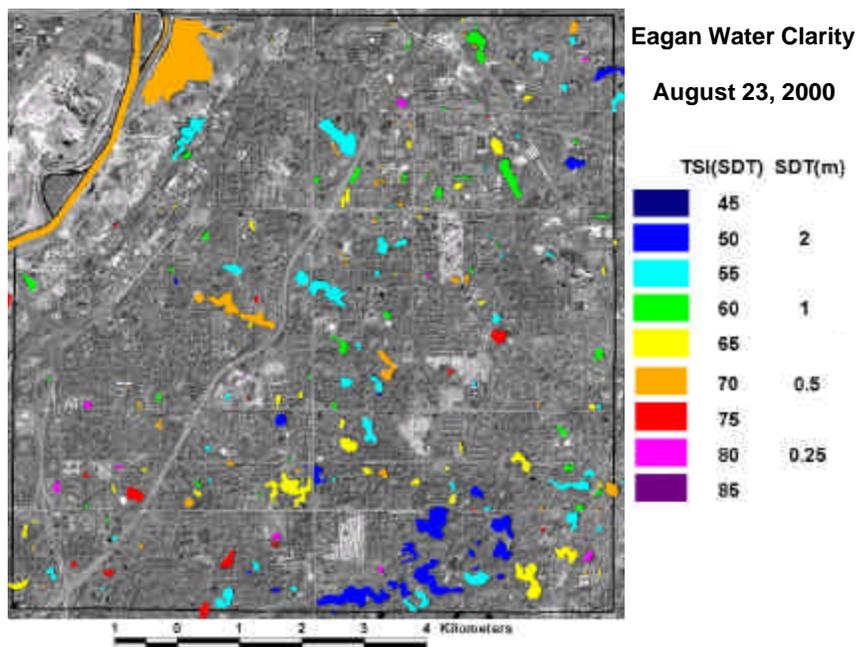


Figure 3. Classification from multispectral IKONOS data overlaid onto panchromatic land image.

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The University of Minnesota’s Remote Sensing and Geospatial Analysis Laboratory (RSL), a unit of the Department of Forest Resources and College of Natural Resources, was established in 1972 and focuses on geospatial research and development for forestry and natural resources.

Current efforts emphasize quantitative approaches to natural resource assessment, carried out in cooperation with resource agencies. Core activities at the RSL include research, education and outreach, and the facilities feature an array of hardware and software for image processing, mapping, modeling, statistical analysis and visualization.