# Advances in Remote Sensing for Agriculture

by
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## Introduction

Remote sensing technology has seen many changes in the past five years. The major changes are that from satellite altitudes we are or will be able to 1) image or see with more detail, a smaller piece of land, 2) define more precisely the specific colors or light responses reflecting off of the field and 3) obtain data on a regular interval of every other day or every 5-7 days. These changes make for real advances to agriculture as we need to be able to view those small areas in the field that are giving us problems, determine what the problem is within a field by interpreting remotely sensed data and receive data/information on a regular interval.

## Spatial Resolution: The Space Between my Data Points

When you view your yield image map, you are looking at about 750 to 1,500 data points per acre depending on how fast you were traveling and how often (1, 2 or 3 seconds) you made a yield measurement. The area that one can see on an image, whether yield monitor or remotely imaged is called "spatial resolution". Spatial resolution in satellite data collection is improving. With current satellites, one can see areas that are 30 meters x 30 meters (4.5 measurements/acre), 20 x 20 meters (10 measurements/acre) and 10 x 10 meters (40 measurements/acre). With future satellites, we will be receiving data that have a variety of spatial resolutions or pixels (short for picture elements) that in some cases will be as detailed as 1 x 1 meter or over 4046 data points per acre.

Table 1. Conversion of Spatial Resolution from Images to Data Points on the Ground.

| Resolution (meters) | Data Points (Pixels)/Acre | Points/Hectare |
|---|---|---|
| 1000 | 0.004 | 0.01 |
| 80 | 0.6 | 1.56 |
| 30 | 4.5 | 11.1 |
| 23.5 | 7.3 | 18.1 |
| 20 | 10 | 25.0 |
| 15 | 18 | 44.4 |
| 10 | 40 | 100 |
| 5 | 162 | 400 |
| 4 | 253 | 625 |
| 3 | 450 | 1111 |
| 2 | 1012 | 2500 |
| 1 | 4046 | 10000 |

In terms of sensor technology, we are seeing improvements in spatial resolutions that allow one to see great detail (Table 2). At recent conferences, we have learned that there is a potential for over 50 land observing satellites to be launched before the year 2007. These satellites which are both government and commercial will have a large range of spatial resolutions from 1 meter to 1 kilometer. The highest resolution is proposed by Space Imaging Inc. and Earthwatch (QuickBird satellite) who plan to launch satellites in the next few years that will have 1 meter panchromatic and 4 meter digital data. EarthWatch (EarlyBird satellite) and other companies like Resource21 and GER are promising data in the 5 to 15 meter spatial range.

Table 2. Remotely Sensed Data Choices of the Future and Some Characteristics.

<u>Satellite Platforms</u>
Spatial Resolutions:
1, 2, 3, 4, 5, 10, 15, 20, 23.5, 30 meters
Spectral Resolutions:
5, 10, 50, 100 nanometers
Temporal Resolutions:
1-5 days, 8-10 days, 14-16 days

<u>Aircraft Platforms</u>
Sensors similar to satellite platforms
Greater flexibility in obtaining coverage
Fly under the clouds!

<u>Tractor Platforms</u>
Potential sensors for organic matter content, pH, soil texture, soil moisture
Sensor measurements relating to specific tasks
Work under a variety of conditions

Note that we are not limited to thinking only about satellite coverage for remotely sensed data. Several companies are providing sensor coverage by airplane from a variety of altitudes at the time that the grower would like to see what is happening to the crop. The other choice is that companies are developing sensors that can provide specific measurements for specific elements or conditions. Purdue University has patented an organic matter sensor that can be used on an implement such as a corn planter or on a lime/fertilizer truck. Other sensors are being developed to measure soil texture, pH and soil moisture which show promise of being a high growth business opportunity.

## Spectral Resolution: The "Various Colors" of my Data Points

When remote sensors talk about the variation of light energy and its measurement, they call it spectral resolution. Improvements in color differentiation and refinement of measurement response have been in measuring a smaller portion of light energy or spectral wavelength bands measured in nanometers. The sensors placed in future satellites will take advantage of technology that will allow for measurements of narrower bands from 100 down to 5 nanometers and therefore a better measurement of the different colors and of areas that the human eye cannot see in the near infrared.

Currently satellites like Landsat have 7 wavelength bands and SPOT has 4 wavelength bands with bandwidths of about 50 nanometers. TRW will launch the Lewis satellite during this next year under a NASA contract with 384 wavelengths. The 5 nanometer bandwidth off the Lewis sensors will certainly provide a more detailed look at the reflective nature of light coming from soil and plant conditions. Other companies will learn from this data in their selection of specific wavelength bands for specific measurements of plant conditions such as stress, nutrient deficiencies and similar variations effecting crop yield.

## Temporal Resolution: The Number of Times that I can see my Data Points

When we look at the same field or location on repetitive dates, we are using temporal resolution. We are looking for the variation that occurs over time or "change detection." With current satellite data, one has the potential of receiving data every 2-6 days (SPOT) or every 16 days (Landsat). Future opportunities will be either 2, 3 or 5 days depending on the company. The value of receiving repeat data would be in identifying a change where one could perform an activity that would correct or improve the change. If you are irrigating, it may be in changing the rate or amount of water, or adding nutrients with the water. If the change is due to some stress factor such as weeds, insects, diseases, or similar pests, one would need to decide if correcting the problem through application of a pesticide would be economical.

Growers are also interested in estimating the yield of their crop prior to harvest. Remotely sensed data, especially with a temporal view, can give valuable clues to the potential yield; however this will vary by growth and maturity of the crop. Not all crops will provide high correlation of vegetation mass to yield. Variation in corn varieties, for example, has shown that some varieties have more vegetative cover than others and may not be related to actual yield. Much work needs to be done in this area. The use of more wavelength bands at narrower bandwidths may also hold promise for determining more information about yield and yield quality.

## Summary & Conclusions:

Remote sensing technology will improve by increasing spatial, spectral and temporal resolutions starting during 1997. There will also be an effort to provide the data within 24-48 hours after it has been acquired. Another technology besides remote sensing that will assist in improving answers and interpretation will be Geographic Information Systems (GIS). The ability to merge soil maps with remotely sensed data to understand crop variability is a great asset to interpretation. Many growers have commented that they would like more detailed soil information than currently provided by the standard soil maps. The ability to take other data such as terrain data, slope, aspect or even other remotely sensed data and look at crop variability causes many people to see many opportunities for better understanding of what is causing the variability.

Where does (GIS) and remote sensing fit with Precision Farming? Several companies are starting to market GIS record-keeping systems so farmers can record all of the field operations such as planting, spraying, cultivation and harvest (along with specific information such as type of equipment used, rates, weather information, time of day performed, etc.). Additionally, the farmers are able to record observations through the growing season such as weed growth, unusual plant stress or coloring and growth conditions. Data collected by the GPS operations can be automatically recorded with the GIS program. Remotely sensed data can be analyzed and added to the GIS using soil maps, digital terrain and field operations information as ground truth.

More attention is being paid to the type of information that farmers will need. It would appear that most remote sensing vendors will not be delivering raw images directly to all farmers. Rather they will provide data/information to the "information multipliers" or the "value-added vendors" such as agricultural business dealers, extension personnel, crop consultants, and special agricultural information services who in turn will analyze and interpret the data and deliver it to the farmer. Farmers are collecting a lot of supporting data and those analyzing the remote sensing data will need to gain access to the farmer's data. Farmers will be in a position to perform their own image analysis but we must remember the needed training aspects for this to be successful.

Advances in remote sensing technology are changing the way we will look at agriculture. The success of remote sensing will be measured by the type of information that is provided to the farmer, how quickly the information is delivered and the fee that is charged for the information. Competition for the farmer's business should help in making the success a reality.

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