Site-Specific Management Guidelines

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SSMG-26

# Interpreting Remote Sensing Data


## Summary

Can remote sensing fulfill its 30-year-old promise for enhancing profitability in agriculture? The answer is still not clear-cut for everyone, but a combination of past experience and technological improvements is now making it profitable to incorporate remote sensing into many farm and ranch enterprises.

This guideline explores some of the basic analysis options for agricultural applications of remote sensing data. Once remote sensing data have been collected, the user must interpret the data to derive the information needed to help make decisions. It is a given that the data and information will have some associated error. As a producer or service provider, you must decide what amounts of certainty are necessary and whether or not the information is worth the investment.


## Some of the Questions

In order to determine how remote sensing might fit into your operation, consider a few questions. The answers to these questions will also help define your approach to analysis. Several of these questions are also discussed in the other remote sensing guidelines.

1. Which problem(s) will be addressed with the remote sensing data?
2. How much detail is needed and when and how often should the data be collected?
3. Which spectral bands will provide the basis for deriving the best information?
4. How quickly is the information needed?
5. Will the data/information be part of a database for future retrieval and manipulation?
6. What are some of the interpretation options available to you; what interpretation alternatives need to be provided by others, namely service providers experienced in remote sensing?

## Partial Answers

**Problems** in agricultural applications can often be addressed with remote sensing. The other site-specific management guidelines (SSMGs) discuss some applications and problems (Potential Applications of Remote Sensing, C. Johannsen, et al., 1999, SSMG #22 and Remote Sensing: Photographic vs. Non-photographic Systems, M. Schlemmer, et al., 1999, SSMG #16). Most agricultural applications of remote sensing involve some sort of stress detection. Other issues such as soil differences, landscape positions, drainage classes, or planning and logistics may also be considered.

**Detail** requirements and data collection **timing** are related to your answers for the first question. For our purposes, we will only consider field-sized data sets collected from aerial or satellite platforms. Satellite systems provide inexpensive and repetitive coverage of the earth, but have not yet achieved the spatial resolution of airborne systems. (See URL: http://rst.gsfc.nasa.gov/start.html for a more detailed discussion of satellite systems.) Yet, in the next few years we can expect to see earth-imaging satellites with multi-spectral sensors collecting data at spatial resolutions of about 3 feet or one meter per pixel. Weekly repeat cycles for data collection have been suggested for several of these systems. In the near-term, aircraft-mounted sensors are the best source for high-detail products.

Note: The term “pixel” is a shortened form of picture element and refers to an area on the earth that contributes the reflected or emitted energy to a sensor. The smaller the pixel the more spatial detail on the resulting imagery. Imagery refers to “hard copies” from sensors other than film; the hard copy for film is the photographic print.

Different problems will require different pixel sizes. If you want to generate a weed map, for example, a one- to three-meter (3 to 10 feet) pixel would be a likely choice for sufficient spatial detail. Conversely, if your objective is to map large geographical areas of drown-out, good results could be achieved with 100 foot pixels. The user needs to consider the end product in order to define the desired pixel size, basing this decision on the smallest object or feature that needs to be distinguished to address the questions at hand (**Figure 1**).

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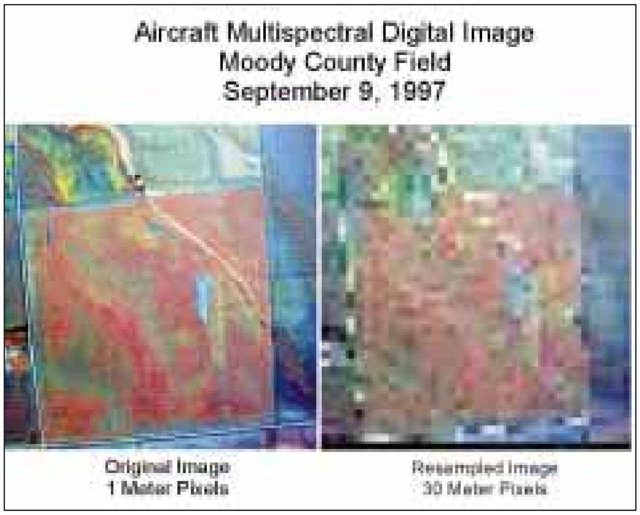


**Figure 1.** **False color imagery of a farm field is represented in two pixel resolutions (1 m versus 30 m pixels). Observable differences in detail between the scenes are obvious from individual trees to drainage definition. Similarities between scenes are seen in the crop vigor (strength of red colors) and northwest-southeast orientation of coloration differences.**

The need for multi-date remote sensing is also best dictated by the objectives of the activity. If a farmer or crop consultant wants to monitor crop stress, a consideration for data collection will be crop growth stage. The data collection timing (during midday and under cloudless conditions) across the growing season could include bare soil, early crop growth stage, peak crop greenness, and crop maturity (dry-down differences) imagery. Because of the capacity for precise timing, aircraft data collection would be best for this application. If a user wanted to map hail damage, one or two data collection dates would likely suffice: an image recorded within a couple of weeks after the storm and, if needed, another image later in the season to show re-greening after light damage. Satellite imagery with coarser levels of detail could work for the hail mapping application.

**Spectral band** availability is limited for most users. Commonly available spectral bands include black and white photography (visible light), color photography (blue, green, and red light), and color infrared photography (green, red, and near infrared light). Satellite systems or sophisticated airborne scanning systems can collect many more bands of data, out into the infrared portions of the spectrum. The question is, how to decide which sensors and bands are right for a given need. The ideal answer lies mainly in knowing how the incoming energy interacts with vegetation, soil and water.

When incoming solar energy strikes a surface, three results occur: reflectance, absorption, and/or transmittance. Typical sensors record reflectance. If we are considering thermal energy, the thermal sensor will be recording emittance as apparent ground temperature. It is the amount (percent) of the reflectance or emittance across the energy spectrum by different objects that helps us to develop spectral patterns (**Figure 2**). While not necessarily unique, these curves help us to interpret the imagery through identification of the energy spectrum areas that spectrally resolve the differences among the features of interest. For example, a healthy crop at a given crop stage will generally look different from a stressed crop. Color infrared imagery is good at recording the difference between a healthy crop (vigorous red color) versus a stressed crop (pinkish red color). Subsequently, the remote sensing data interpretation will often require field checking to determine the cause of the stress.

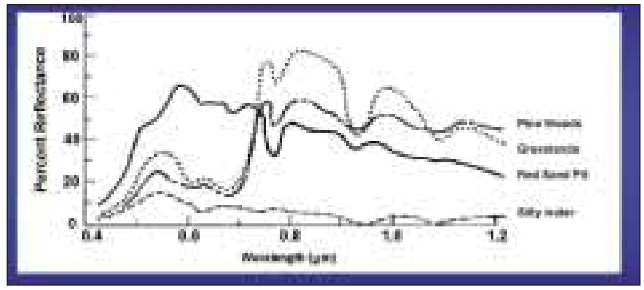


**Figure 2.** **Typical reflectance of four features is plotted across a part of the electromagnetic spectrum from blue light to near infrared light. Note the characteristic "jump" in reflectance between 0.7 and 0.8 µm (where reflective infrared begins) for growing vegetation as well as the differences in curves between grasslands and pine.**

**Information** from remote sensing can used to take immediate action, such as weed mapping and spraying decisions or the evaluation of over- or under-watering by irrigation equipment. Examples of other less immediate decisions could involve locating crop-based evidence of a plugged tile line (post-harvest action) or looking at the distribution of perennial weeds in fields after the crops have matured (pre-planting action for next growing season). Numerous other examples could be discussed, but you, as the user, must determine if a cost-effective solution exists for a given problem and what the immediacy is for that problem solution.

**Databases** require digital (computerized) data. Geo-rectified data that are tied to known map locations are strongly recommended for retrievable records. The latitude and longitude coordinates are needed for your field corners. We can look at field changes on the imagery within a season and across different years (until the field boundaries are changed). The geo-rectified data also allow overlaying with other mapped data, such as yield maps, plant population data, variety data, and topographic data. Geographic information systems (GIS) offer the best software tools for integrating remote sensing information with other information, but GIS requires geo-rectified data.

**Visual interpretation** of remote sensing data with appropriate field checking is perhaps the best way to begin understanding what the imagery reveals for agricultural applications. This process utilizes the human computer (your brain) to derive information through interpretation of the remote sensing data. The other interpretation option is to use computer classification software. Both of these options are discussed below.

The factors of visual interpretation are color (or tone for black and white photos), pattern, shape, size, and texture. For example, if we are mapping rock piles in a field, the factors of size, shape and color will likely be the main criteria for differentiation. Generally, we learn how to visually interpret imagery by first identifying the features on the imagery that we know, such as tree lines, ponds and roads. Next, the interpreter should locate some areas on the image (within your fields) that are distinctly different from the known areas. These areas should be tagged by latitude and longitude markers for ground-truthing as well as for possible inclusion of data into a GIS. Finally, take the image in-hand and go to the areas in question and identify the features. Global positioning system (GPS) technology will be useful in the last step, particularly if a location grid is superimposed on the image.

Looking at your own fields or familiar areas on the imagery is the best way of gaining experience in imagery interpretation. The interpreter must keep in mind that several features can change with time, and this can affect how the features are recorded on the imagery. Some examples of dynamic situations are: 1) wetlands drying up, 2) soil color changing as it dries, 3) crops growing and maturing, and 4) weeds intermingling with the crops. Additionally, the imagery is often collected under different atmospheric and sun angle conditions across a season and will not show the same features exactly the way they were shown previously. One way to recognize that this is happening is to look at features that should not change in a short turn-around time, such as gravel roads or trees (fully leafed out). If it is necessary, radiometric correction may be required to remove these apparent differences. Your imagery contractor should offer you alternatives for this service.

Color imagery or photography represents the earth in colors that we are used to seeing. Color infrared (CIR) imagery or photography uses a near-infrared (NIR) channel. Since our eyes are not sensitive to NIR, we need to represent this reflectance in colors that we can see. Consequently, CIR imagery is often referred to as false color imagery. It is useful in agriculture because the spectral patterns of growing vegetation show a uniquely rapid increase in reflectance at the boundary between the red and NIR bands (**Figure 2**). Typically, growing vegetation is displayed in red tones on CIR imagery. The red colors represent the high NIR reflectance and the relatively low reflectance (little contribution from the blue and green colors) in the visible bands. Solid, deep red colors most often indicate healthy vegetation. If we see differences in the red tones within a field, we may be able to tell something about variability in plant vigor, growth stage or plant population. Different crops will often appear in different shades of red depending on crop stage, vigor, wetness, weeds, etc. Since changes in reflectance of NIR energy by plants is typically very sensitive, we can often detect stress, for example, with CIR photography before it can be seen with the naked eye.

Thermal imagery represents apparent surface temperatures, which are in turn influenced by temperatures below the surface to a shallow depth. Moist soil will tend to be cooler than dry soil during the day. At night the opposite result occurs due to heat storage by the moist soil. Crop canopies are cool during the day because of evapotranspiration. Daytime rises in canopy temperature indicate that some type of plant stress is happening, for example, moisture, disease, or insect problems.

The spectral differences among different objects/surfaces are often subtle, whether at visible, NIR or thermal wavelengths, and will require field verification. Other times the spectral differences on the imagery will be clear, but we will still need to visit the site to determine what is represented by these differences. Visual interpretation can be completed as soon as the imagery is delivered. **Figure 3** shows an example of a single-band image with annotations of the representative weed species found on field inspection.

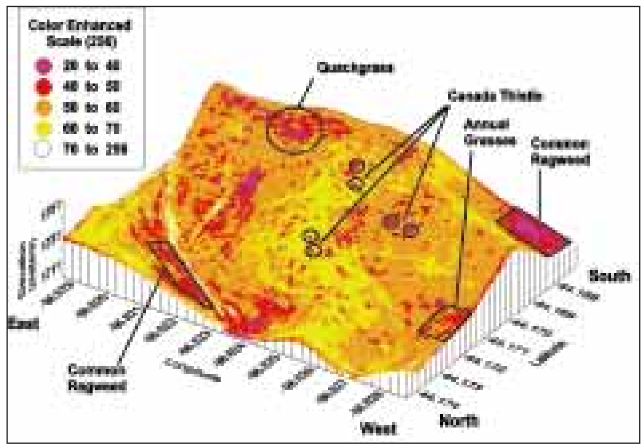


**Figure 3. A single spectral band is superimposed on a 3-D topography map of a post-harvest 160-acre farm field located in eastern South Dakota. The annotation represents field checking for weed populations. Different colors and shapes help to identify the anomalous areas.**

The strength of remote sensing lies in efficiency of interpretation and extrapolation. Once we’ve confirmed a spectral pattern through ground observation, we can assume that all similar signatures are probably the same within that image.

Crop scouting can often be improved using visual interpretation of remote sensing data. The scout can select field observation sites/lines based on the anomalies seen on the imagery. The time spent in the field is, thus, more effective, and the scout learns more of what is happening in the field. For example, a disease/nutrient problem may be occurring in the middle of the field. It is unlikely that this problem will be seen from the road or even during brief walks into the field edges. Using remote sensing, the problem has a much better chance of being observed, and corrective treatments can be applied.

**Computer digital classification** is complex and often involves expensive software. Supervised and unsupervised classifications are the two main types of computer classification for data interpretation. In supervised classification the computer is used to classify the image according to what the user has identified as training data. The identification of training data is a step where several areas of a particular class, e.g. weed patches, are identified and "circled" with a mouse in the computer-displayed imagery. The data are digitally extracted and spectrally characterized by the software. The computer then finds all the pixels in the image with this same spectral pattern. The user can define as many classes as needed, defining training data for each class. It is important to develop relatively homogeneous training data. Depending upon one's computer experience, at least two days should be allowed for this process when several fields are involved.

In unsupervised training, the computer will aggregate the digital image according to the number of categories that the user has specified. The computer does all classifying work, but we must make sense of the results. Think of it as the same as supervised classification, but without the training data. **Figure 4** shows an example of unsupervised classification for weed mapping.

Two other computer applications are also important: geometric rectification and ratioing. The rectification process of the imagery allows relatively accurate positions to be determined so that area measurements can be made. Latitude and longitude points are located on the computer-displayed imagery, and a software algorithm then transforms (and redisplays) the image to remove much of inherent distortion. It is strongly recommended that the contractor who supplies your imagery should provide geometrically rectified imagery. Pre-processed satellite imagery will usually be relatively distortion-free and generally will not need additional geometric processing. Rectification also allows the digital imagery to be incorporated into a GIS.

Ratioing involves a mathematical manipulation of the digital numbers (spectral reflectance). A well-known ratio is the Normalized Difference Vegetative Index (NDVI), which is computed as follows: NIR band – red band divided by NIR band + red band. The resulting image emphasizes differences in vegetative "greenness" and is often used with digital imagery to determine plant condition or status.

## Planning and Investment

Several means of considering applications of remote sensing in agriculture can be undertaken. Probably the most economical and unbiased is to select a field which has some variability and have some aerial photography taken two or three times during the growing season. After each mission, visually interpret the imagery or photographs and then go to the field to see what you can learn. A cost of around $1 per acre per flight would be an average imagery expense for this activity. Working with a crop consultant who is experienced in remote sensing is a good option for further evaluation.

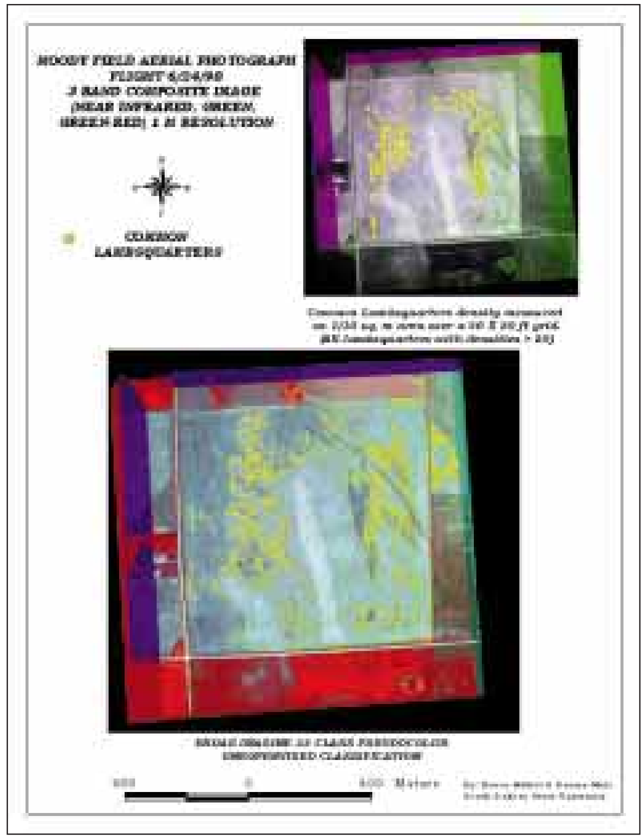

**Figure 4. Unsupervised classification of a multi-band, 1-m image shows that success in locating weeds increases as the weed count increases per unit area (Clay, S.A. and G. Johnson. 1999. Scouting for Weeds. SSMG No. 16. *In* Clay et al. (ed.), Potash & Phosphate Institute.)**

Satellite imagery is another option. While it is inexpensive on a per-acre basis, each image is relatively costly because a large area is covered. Added costs of satellite imagery also might include computer processing and comparatively poor spatial resolution (see "big pixels" in **Figure 1**) and an inability to schedule image collection according to the schedule you prefer (as done with aerial photography). We anticipate the costs of digital data to continue declining as more competition emerges. Currently, satellite and other remote sensing data can be purchased through the USGS EROS Data Center (URL: http://edcwww.cr.usgs.gov/ or telephone 605-594-6511) and a few other places such as the satellite vendors themselves. ■


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