Site-Specific Management Guidelines

M. Schlemmer, J. Hatfield, and D.C. Rundquist

SSMG-16

Remote Sensing: Photographic vs. Non-Photographic Systems

Summary

The intention of site-specific management is to optimize grower inputs on areas much smaller than the entire field. These areas may be as small as a few square meters in size. To manage a field on such a scale, data would have to be collected on a similar or smaller scale. To collect the data by hand would be very time consuming, labor intensive, and destructive. This is the role remote sensing systems can play in site-specific management. The purpose of this guideline is to compare the advantages and disadvantages for two types of remote sensing systems: photographic and non-photographic. It is also intended to provide basic information about remote sensing and how to deal with the data obtained.

Introduction

"Remote sensing is defined as the acquisition of information about an object without being in physical contact with it" (Elachi, 1987). A simple example is when our eyes sense the reflected light from an object and our brain interprets the information. In this example, our eye is the detector and our brain is the computer that makes sense out of what was detected. Remotely sensed information can be in the form of potential fields, force distribution, acoustic waves, or electromagnetic energy. The main focus of remote sensing in agriculture is the interaction of plants and soil with electromagnetic energy. The sensors utilized can be grouped into two main categories, photographic and non-photographic. Both provide information about electromagnetic energy and how it interacts with the surface being viewed.

What is electromagnetic energy? **Figure 1** illustrates the electromagnetic spectrum. Visible light is a very small portion of the electromagnetic spectrum. Sources of this energy can be man-made or naturally occurring. Natural sources of electromagnetic energy are the sun and earth. Both emit energy, but do so at different wavelengths. As such, features on earth can be observed and characterized by the reflected solar energy and/or the emitted terrestrial energy. These types of sensors are referred to as passive systems. Most of the solar energy available at the earth's surface generally ranges in wavelength from 0.3 μm to 3.0 μm. The visible portion (0.4 μm to 0.7 μm), of which we are most familiar, covers a very small segment of all solar energy. Most of the energy emitted by the earth occurs between 3.0 μm and 14.0 μm, the peak of which is near 9.9 μm. Sensors can be built to measure the energy in much longer wavelengths, such as radar, which is in the microwave region of the spectrum. The energy these systems sense is that which originates from the system itself, referred to as an active system. A pulse of energy at the longer wavelength is sent out from the device, and the reflection off the target is measured.

Energy sensed from plant and soil surfaces can provide useful information for decision making. For example, differences in soil color following spring tillage can be used to identify nutrient management zones. Also, differences in the reflectance of weeds and crops can be used to identify areas requiring additional weed control.

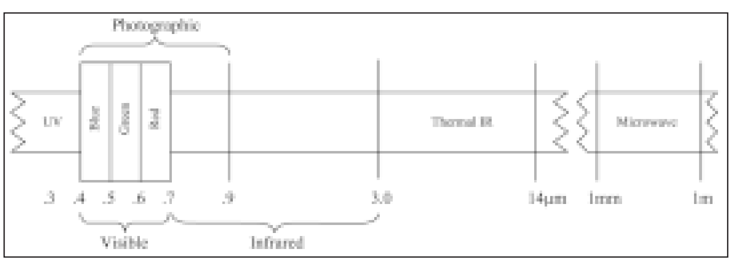

Figure 1. The electromagnetic spectrum.

Remote Sensing Applications and Considerations

Remote sensing of agricultural fields has been used for a variety of applications ranging from assessment of water or nutrient status to detection of weeds and insects. There are a number of crop stresses that can be detected through remote sensing. However, to apply this technology

The Site-Specific Management Guidelines series is published by the Potash & Phosphate Institute (PPI) • Coordinated by South Dakota State University (SDSU)
Sponsored by the United Soybean Board (USB) and the Foundation for Agronomic Research (FAR). For more information, call (605) 692-6280. www.ppi-far.org/ssmg

requires an understanding of the limits and capabilities of remote sensing. The three primary factors are spectral, spatial, and temporal resolution.

Current applications of remote sensing involve comparing the reflectance of a surface to the reflectance of a known target surface. Treatment effectiveness or spatial variability can be evaluated by comparing reflectance with that from a reference of choice (e.g., well fertilized area). Reflectance in the green and red bands is typically associated with chlorophyll, while near-infrared reflectance is strongly associated with cell and canopy structure. Another common application is to use vegetative indices that are based on combinations of wavebands. The most common of these indices are those that compare a portion of the visible spectrum (red or green wavebands) with the near-infrared. This combination of wavelengths is extremely sensitive to changes in vegetative cover and condition. Other current applications include the identifying of management zones based on soil color. These zones can be delineated by computer aided classification techniques of both photographic and non-photographic data. Application of remote sensing can provide a consultant or grower with a scouting tool for pre-plant and post-emergent nutrient management as well as pest management through the locating of potential weed, insect, and disease infestations.

Considerations of Spectral Resolution Spectral resolution is important to the development of vegetative indices. If the wavebands are too broad, the unique reflectance characteristics associated with vegetation can be degraded. If the spectral selection is too narrow, the result may be more noise than signal, which can lead to false interpretations.

Considerations of Spatial Resolution The spatial resolution of an image is defined as the area on the ground that can be resolved by a single picture element (pixel). This is the most difficult problem to address. Pixel size (lowest unit of resolution in an image) should match the application. Satellite images that are commonly shown on TV as part of weather forecasts have pixel sizes that cover several square miles. This level of resolution is too coarse to make management decisions within individual fields. The optimum spatial resolution for agriculture may be determined by the width of the implements being used or based on the smallest object required for identification. With all the technological advances made on digital camera systems, the highest spatial resolution can still be obtained with the photographic sensor. Photographic and non-photographic images that are flying at similar altitudes will not have similar spatial resolution characteristics. The spatial resolution of photographic images are generally much better than that of non-photographic images.

Considerations of Temporal Resolution Temporal resolution is the re-visit time between successive images. An aircraft mounted camera or scanner offers greater flexibility for data acquisition. The cycle is dependent on aircraft availability and the weather. Satellites have a fixed repeat cycle that ranges from a few days to as many as 16 days. Unfortunately, many of the wavebands on satellite systems can not penetrate through clouds and thus meaningful images are limited to clear days. Image quality may even be poor on days with high, thin cirrus clouds. High temporal resolution may be important during periods of rapid crop growth when decisions need to be made that affect potential crop yield. This would require that images be collected with a high frequency during early vegetative development and when the crop enters the reproductive stage.

Sensor Type

The sensors common to agricultural applications are most generally airborne systems and are grouped as photographic and non-photographic.

Photographic Sensors Photographs can be thought of as consisting of a network of many tiny electromagnetic energy detectors. The photographic spectrum utilized by these detectors ranges from 0.3 mm to 0.9 mm. For black and white film, the individual detectors are the grains of silver halide in the film emulsion. Color and color IR film contains no silver. Rather, the image is created when light interacts with chemicals on the film. The absorption characteristics of the three dye layers (yellow, magenta, and cyan) generate the various colors. The developed film will provide information about the variability within a grower's field.

If the desire is to compare images over time or relate reflectance values to crop/soil conditions, then calibration of the image is required. For quick calibration of images over the same field select several objects for which reflectance does not change over time. Choose the image that will be considered your base map. All other images of the same area will be calibrated to the base map. Adjust the entire image by applying the equation that describes the relationship between the brightness of each object in the base map and the brightness of those objects for each of the other images.

To accurately express a film exposure quantitatively, one must acquire an exposure of a calibrated wedge having steps of known transmittance (**Figure 2**) with a standard source of energy transmitting through it.

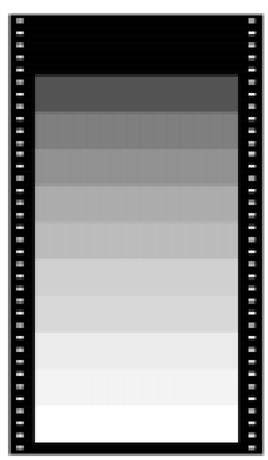

Figure 2. Calibrated wedge strip of known transmissivity.

The exposure of the calibrated wedge along with densitometer or scanner measurements (**Figure 3**) for each step wedge of the developed film can provide a numerical relationship between the film's optical density and the exposure of some known transmissive feature.

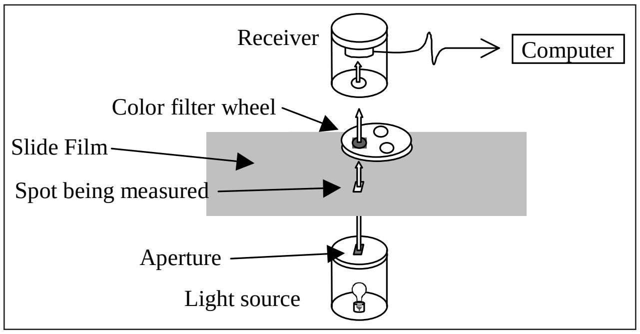

Figure 3. The process and components of making a densitometer measurement.

The result of this relationship can then be applied to each exposure for that roll of film. The product is an image that more accurately represents some surface condition. This should be done for each roll of film used. The results from the exposure may vary and will be dependent on film types, different manufacturing batches, different developers, developing time, and temperature.

The resolution of photographic systems is a function of film and lens resolving power, flight motion, and height above ground. Primarily, it is a function of the granularity of the film. The higher the granularity, the lower the spatial resolution. The implication is that faster films have higher granularity and lower spatial resolution. Film of 64 or 100 ASA is commonly used for aerial photography. Ground resolution can be calculated by dividing the reciprocal of the image scale by the system resolution (Lillesand and Kiefer, 1987).

Non-photographic Sensors Multispectral scanners, or non-photographic devices, provide the opportunity to sense several wavebands in a wider range of discrete wavelengths than does a photographic sensor (**Figure 4**).

Hyperspectral scanners provide the opportunity to sense many very narrow wavebands over a wide range of wavelengths. However, they do so with a much greater number of sensors. Multispectral systems measure energy in specific, strategically placed portions of the electromagnetic spectrum. The hyperspectral systems measure several consecutive wavebands across a specified region of the electromagnetic spectrum. These sensors measure the energy and store the data in a digital form. The stored digital number of each pixel in the multispectral system represents the energy reflected from some area on the ground. That area is a function of the image array size and the altitude of the sensor platform (**Figure 5**). To calculate the ground resolution of the multispectral system, divide the ground swath width of the sensor by the image array width.

The non-photographic sensors will still need to be calibrated periodically if surface reflectance or multi-date analysis is desired, much like that of the photographic sensors. Sensors can be designed to measure the available solar and terrestrial energy, usually from 0.3 µm to 14 µm. These systems are known as passive sensors because they sense energy originating from an outside source. Active systems generate the energy being sensed. The active systems are generally in the microwave region of 1 mm to 1 m wavelengths, but can be at any wavelength. An example of these types of systems would be radar in the microwave, laser systems in the visible portion of the spectrum, and the EM sensors that measure electrical conductivity.

Advantages and Disadvantages

When properly acquired and calibrated, aerial photographs can be used to measure the spectral reflectance of

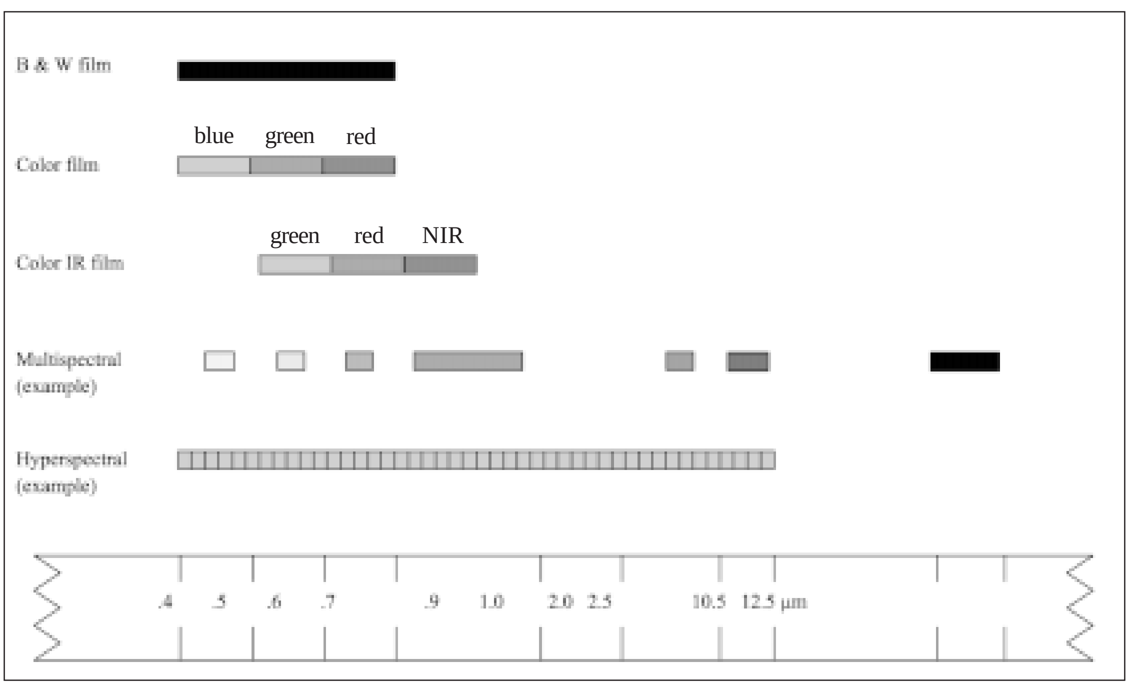

Figure 4. A graphical representation of the regions in which photographic and multispectral scanners sense.

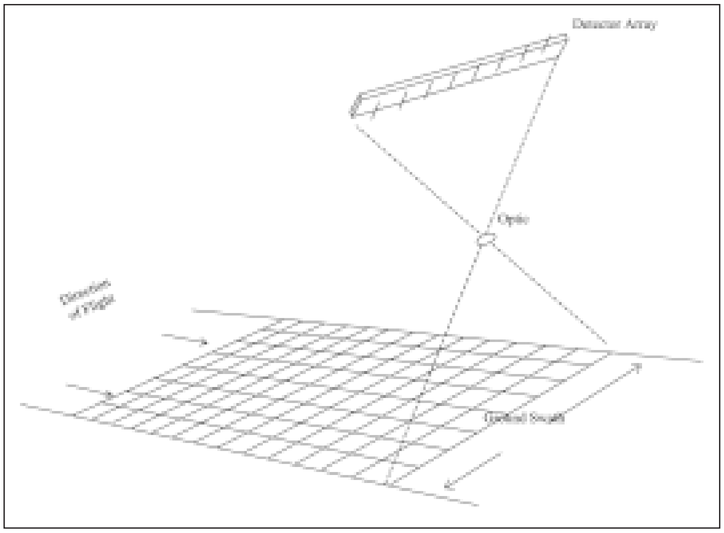

Figure 5. A linear array pushbroom multispectral scanner.

surface features as can non-photographic systems. The non-photographic systems have an advantage in that they acquire and store the data in digital form immediately. Therefore, calibration of non-photographic systems can be easier. They also have the advantage when it comes to measuring in more discrete wavelengths over a much larger range of wavelengths and intensities. Photographic systems offer the advantage of greater spatial resolution and a lower cost than that of a non-photographic system. If the application requires high spatial resolution and the broad bands are acceptable, then a photographic system may be appropriate. If the application requires narrow bands and/or bands beyond the photographic range, then the non-photographic system is necessary. Photographic systems may be most appropriate for single event qualitative descriptions of field condition (e.g., soil color or relative crop status). A qualitative analysis of the photographic imagery is low cost since it does not require extensive image calibration, and the equipment is relatively inexpensive. System selection should be based on the needs and requirements of each individual user for each application. ■

References:

Elachi, C. 1987. Introduction to the physics and techniques of remote sensing. John Wiley & Sons, New York, New York USA.

Lillesand, T.M. and R.W. Kiefer. 1987. Remote sensing and image interpretation. 2nd ed. John Wiley & Sons, New York, New York USA.

This Site-Specific Management Guideline was prepared by:

Mr. Mike Schlemmer
Physical Scientist
USDA-ARS
119 Keim Hall
Agronomy Department
University of Nebraska
Lincoln, NE 68583-0915
Phone: (402) 472-8494
E-mail: mschlemmer1@unl.edu

Dr. Jerry Hatfield
Laboratory Director
USDA-ARS
National Soil Tilth Laboratory
2150 Pammel Drive
Ames, IA 50011-3120
Phone: (515) 294-5723
E-mail: hatfield@nstl.gov

Dr. Donald C. Rundquist
Professor
School of Natural Resource Sciences
Director
Center for Advanced Land Management
Information Technologies (CALMIT)
University of Nebraska
113 Nebraska Hall
Lincoln, NE 68588-0517
Phone: (402) 472-7536
E-mail: dr1000@tan.unl.edu

Ref. # 99086/Item #10-0016