AE1262

Agricultural Remote Sensing Basics

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When farmers or ranchers observe their fields or pastures to assess their condition without physically touching them, it is a form of **remote sensing**. Observing the colors of leaves or the overall appearances of plants can determine the plant's condition. Remotely sensed images taken from satellites and aircraft provide a means to assess field conditions without physically touching them from a point of view high above the field.

Most remote sensors see the same visible wavelengths of light that are seen by the human eye, although in most cases remote sensors can also detect energy from wavelengths that are undetectable to the human eye. The remote view of the sensor and the ability to store, analyze, and display the sensed data on field maps are what make remote sensing a potentially important tool for agricultural producers. Agricultural remote sensing is not new and dates back to the 1950s, but recent technological advances have made the benefits of remote sensing accessible to most agricultural producers.

Remote Sensing . . . How You Can Use It On Your Farm

Remotely sensed images can be used to identify nutrient deficiencies, diseases, water deficiency or surplus, weed infestations, insect damage, hail damage, wind damage, herbicide damage, and plant populations.

Information from remote sensing can be used as base maps in variable rate applications of fertilizers and pesticides. Information from remotely sensed images allows farmers to treat only affected areas of a field. Problems within a field may be identified remotely before they can be visually identified.

Ranchers use remote sensing to identify prime grazing areas, overgrazed areas or areas of weed infestations. Lending institutions use remote sensing data to evaluate the relative values of land by comparing archived images with those of surrounding fields.

The Electromagnetic Spectrum

The basic principles of remote sensing with satellites and aircraft are similar to visual observations. Energy in the form of light waves travels from the sun to Earth. Light waves travel similarly to waves traveling across a lake. The distance from the peak of one wave to the peak of the next wave is the wavelength. Energy from sunlight is called the electromagnetic spectrum.

The wavelengths used in most agricultural remote sensing applications cover only a small region

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of the electromagnetic spectrum. Wavelengths are measured in micrometers (µm) or nanometers (nm). One um is about .00003937 inch and 1 µm equals 1,000 nm. The visible region of the electromagnetic spectrum is from about 400 nm to about 700 nm. The green color associated with plant vigor has a wavelength that centers near 500 nm **(Figure 1)**.

Wavelengths longer than those in the visible region and up to about 25 µm are in the infrared region. The infrared region nearest to that of the visible region is the near infrared (NIR) region. Both the visible and infrared regions are used in agricultural remote sensing.

Electromagnetic Energy and Plants

When electromagnetic energy from the sun strikes plants, three things can happen. Depending upon the wavelength of the energy and characteristics of individual plants, the energy will be reflected, absorbed, or transmitted. Reflected energy bounces off leaves and is readily identified by human eyes as the green color of plants. A plant looks green because the chlorophyll in the leaves absorbs much of the energy in the visible wavelengths and the green color is reflected. Sunlight that is not reflected or absorbed is transmitted through the leaves to the ground.

Interactions between reflected, absorbed, and transmitted energy can be detected by remote sensing. The differences in leaf colors, textures, shapes or even how the leaves are attached to plants, determine how much energy will be reflected, absorbed or transmitted. The relationship between reflected, absorbed and transmitted energy is used to determine spectral signatures of individual plants. Spectral signatures are unique to plant species.

Remote sensing is used to identify stressed areas in fields by first establishing the spectral signatures of healthy plants. The spectral signatures of stressed plants appear altered from those of healthy plants. **Figure 3** compares the spectral signatures of healthy and stressed sugarbeets.

Stressed sugarbeets have a higher reflectance value in the visible region of the spectrum from 400-700 nm. This pattern is reversed for stressed sugarbeets in the nonvisible range from about 750-1200 nm. The visible pattern is repeated in the higher reflectance range from about 1300-2400 nm. Interpreting the reflectance values at various wavelengths of energy can be used to assess crop health.

The comparison of the reflectance values at different wavelengths, called a vegetative index, is commonly used to determine plant vigor. The most common vegetative index is the normalized difference vegetative index (NDVI). NDVI compares the reflectance values of the red and NIR regions of the electromagnetic spectrum. The NDVI value of each area on an image helps identify areas of varying levels of plant vigor within fields.

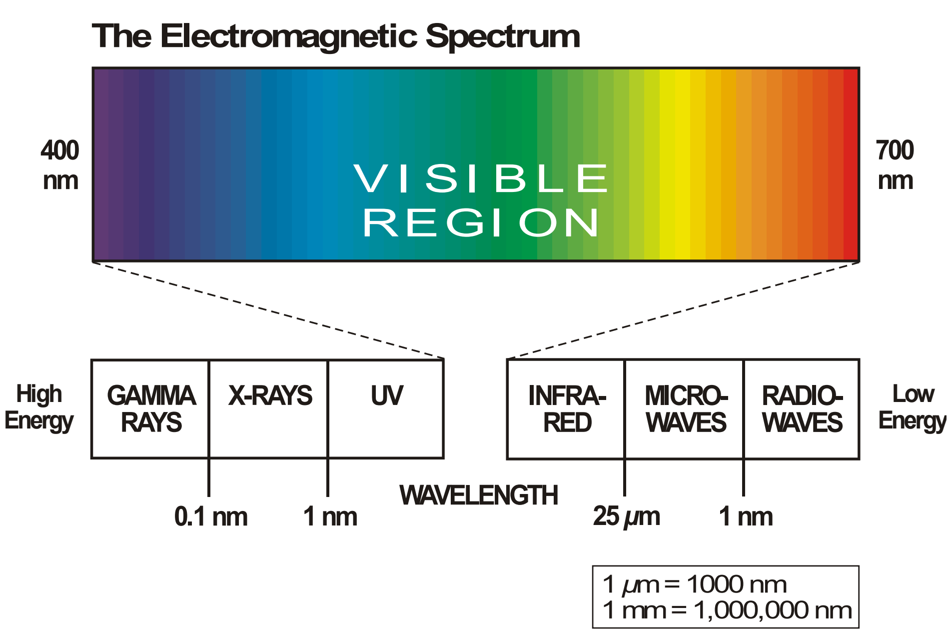

Figure 1. The visible region of the spectrum ranges from about 400 to 700 nm (Kyllo, 2004).

How Does Remote Sensing Work?

There are several types of remote sensing systems used in agriculture but the most common is a passive system that senses the electromagnetic energy reflected from plants. The sun is the most common source of energy for passive systems. Passive system sensors can be mounted on satellites, manned or unmanned aircraft, or directly on farm equipment.

There are several factors to consider when choosing a remote sensing system for a particular application, including spatial resolution, spectral resolution, radiometric resolution, and temporal resolution.

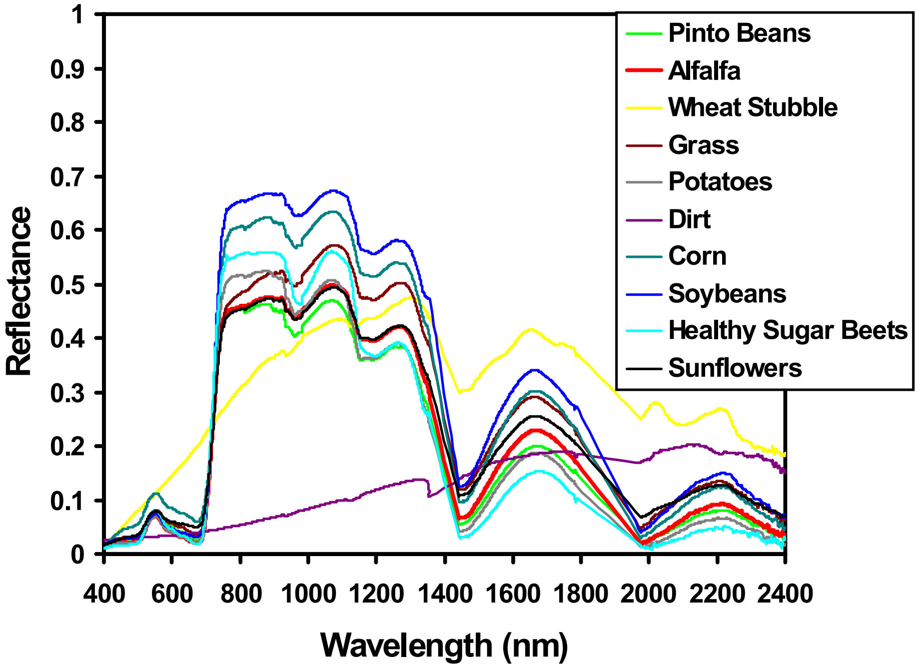

Figure 2. Spectral signatures of crops and soil (Kyllo, 2003).

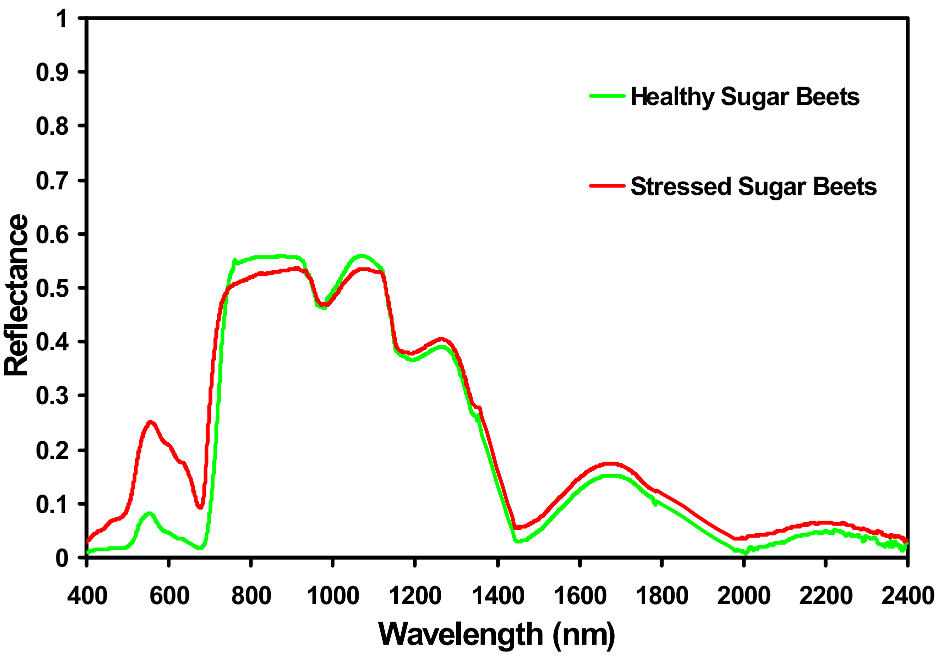

Figure 3. Spectral signatures of healthy and stressed sugarbeets (Kyllo, 2003).

Spatial resolution refers to the size of the smallest object that can be detected in an image. The basic unit in an image is called a pixel. One-meter spatial resolution means each pixel image represents an area of one square meter. The smaller an area represented by one pixel, the higher the resolution of the image.

Spectral resolution refers to the number of bands and the wavelength width of each band. A band is a narrow portion of the electromagnetic spectrum. Shorter wavelength widths can be distinguished in higher spectral resolution images. Multi-spectral imagery can measure several wavelength bands such as visible green or NIR. Landsat, Quickbird and Spot satellites use multi-spectral sensors. Hyperspectral imagery measures energy in narrower and more numerous bands than multi-spectral imagery. The narrow bands of hyperspectral imagery are more sensitive to variations in energy wavelengths and therefore have a greater potential to detect crop stress than multi-spectral imagery. Multi-spectral and hyperspectral imagery are used together to provide a more complete picture of crop conditions.

Radiometric resolution refers to the sensitivity of a remote sensor to variations in the reflectance levels. The higher the radiometric resolution of a remote sensor, the more sensitive it is to detecting small differences in reflectance values. Higher radiometric resolution allows a remote sensor to provide a more precise picture of a specific portion of the electromagnetic spectrum.

Temporal resolution refers to how often a remote sensing platform can provide coverage of an area. Geo-stationary satellites can provide continuous sensing while normal orbiting satellites can only provide data each time they pass over an area. Remote sensing taken from cameras mounted on airplanes is often used to provide data for applications requiring more frequent sensing. Cloud cover can interfere with the data from a scheduled remotely sensed data system. Remote sensors located in fields or attached to agricultural equipment can provide the most frequent temporal resolution.

Remote Sensing: The Complete Process

Figure 4 illustrates a satellite remote sensing process as applied to agricultural monitoring processes. The sun (A) emits electromagnetic energy (B) to plants (C). A portion of the electromagnetic energy is transmitted through the leaves. The sensor on the satellite detects the reflected energy (D). The data is then transmitted to the ground station (E). The data is analyzed (F) and displayed on field maps (G).

References

Adamchuk, V.I., Perk, R.L., & Schepers, J.S. (2003). *Applications of Remote Sensing in Site-Specific Management*. University of Nebraska Cooperative Extension Publication EC 03-702.

Bauer, M.E. (1985). Spectral inputs to crop identification and condition assessment. *Proceedings of the IEEE*, 73, No. 6, 1985, 1081.

Hatfield, J.L. & Pinter, P.J.Jr. (1993). *Remote sensing for crop protection* (Publication No. 0261-2194/93/06/0414-09). Ames, IA: USDA – Agricultural Research Service.

Jackson, R.D., & Huete, A.R. (1991). Interpreting vegetative indices. *Preventative Veterinary Medicine*, 11, 185-200.

Kyllo, K. P. (2003). NASA funded research on agricultural remote sensing, Department of Space Studies, University of North Dakota.

Moran, M.S., Inoue, Y., & Barnes, E.M. (1997). Opportunities and limitations for image-based remote sensing in precision crop management. *Remote Sensing of Environment*, 61, 319-346.

National Academy of Sciences. (1997) *Precision Agriculture in the 21st Century*.

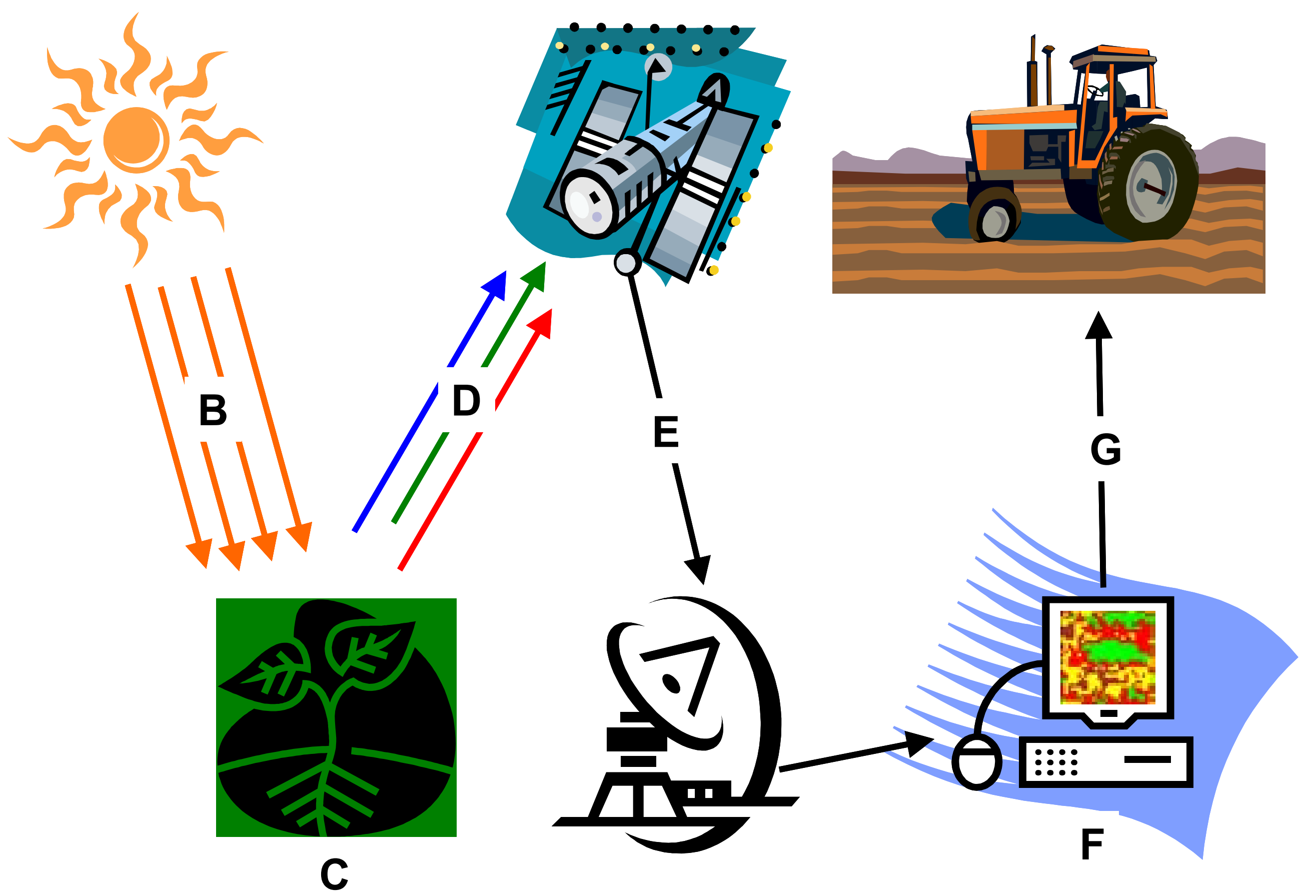

Figure 4. The remote sensing process.

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