REMOTE SENSING OPPORTUNITIES FOR CROP MANAGEMENT

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Precision farming is an information- and technology-based farm management system to identify, analyze, and manage variability within fields for optimum profitability, sustainability, and protection of the land resource. Precision farming calls for managing areas much smaller than whole fields, sometimes as small as a few square feet. Remote sensing represents an important source of data for precision farming, providing information on spatial variation resulting from soil and crop characteristics. Proposed uses of remotely sensed data include detection of crop stresses, pest management, fertility management, irrigation systems monitoring, damage assessment for insurance adjustment, and many more yet undiscovered innovations. The goals of this presentation are to provide a simple overview of remote sensing principles, how to obtain and use remote sensing data, and summarize research under way in our group designed to improve nitrogen use efficiency in corn production using remote sensing technologies.

Remote Sensing Principles

Remote sensing is the science of getting information about an object by acquiring data with a device not in contact with that object. Our eyes and ears are examples of remote sensing devices. Every physical object on the earth's surface absorbs or reflects electromagnetic (EM) radiation. The ultimate source of this radiation is the sun. EM energy travels through space in waves at the speed of light. Objects also emit EM radiation as a function of their temperature. EM radiation is characterized as consisting of a wide range of wavelengths, going form short wave ultraviolet (UV) to long wave microwaves (Figure 1). The visible spectrum represents only a small region of EM radiation (0.4 – 0.7 micrometer, 1 micrometer = one millionth of a meter). Ultraviolet and infrared radiation are not visible to the human eye and must be remotely sensed with other devices. Objects absorb and reflect various wavelengths as functions of their physical and chemical properties. For example, healthy wheat leaves appear green to our eyes because they contain a pigment called chlorophyll, which absorb all radiation impinging upon it except for the green wavelength, leaving only green light to be reflected. This reflected radiation is the color perceived by our eyes. Camera film or other remote sensors also record the same green color.

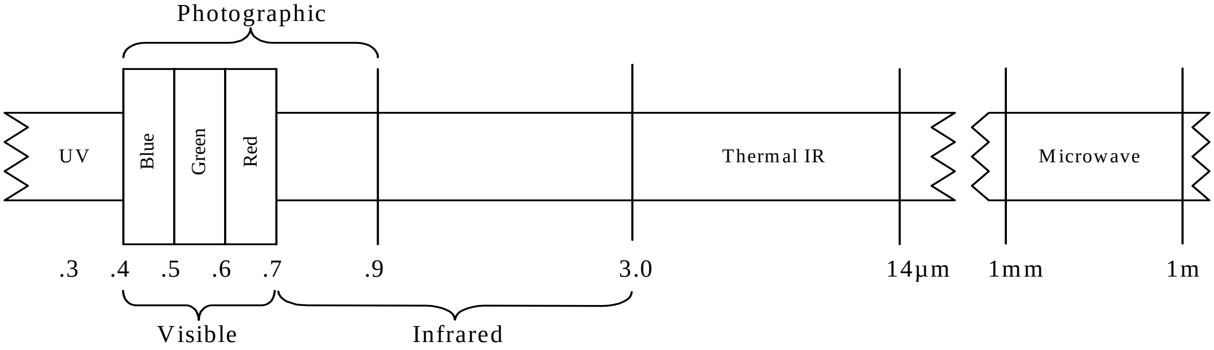

Figure 1. Electromagnetic spectrum, with shortwave energy depicted to the left and long wave to the right.

Obtaining Remote Sensing Data

Remote sensing is generally done by observations from airplanes or satellites, with airplanes generally providing very high resolution over limited areas, and satellites providing lower resolution, but over the entire planet. A remote sensing satellite system entails one or more orbiting spacecraft with a stable platform for sensors (cameras) and a means of transmitting data back to the ground. Remote sensing from aircraft is done with digital- or film-based camera systems. Remote sensing can also be done with sensors mounted on ground-based platforms like tractors.

Important attributes of remote-sensing systems include spatial resolution, spectral coverage, and temporal frequency. Spatial resolution describes the level of detail, or smallest size of an object that can be identified. An image’s spatial resolution can also be described as the closest that two objects can be together and still be distinguished reliably. With images taken at three-meter resolution, for example, cars can be distinguished from trucks, while with images taken at 10-meter resolution neither cars nor trucks can be identified. Present civilian satellite systems have spatial resolutions that range from 10 meters to 4 kilometers. A number of civilian systems have been recently launched (and others have been proposed for launch within the next several years) that will provide images at 1-5 meter resolution.

Spectral coverage refers to how many different colors and different parts of the wavelength spectrum are measured. When data from the different wavelengths are combined (by a computer), the resulting images reveal far more about the Earth's surface than images that record only visible light. Systems today take from one to seven measurements of light energy for each target area.

Temporal frequency refers to the cycle of coverage, or how often data are collected from a particular satellite. The temporal frequencies of operating remote sensing satellites ranges from one satellite pass every month to two every day.

Remote sensing systems make tradeoffs between spatial resolution, spectral coverage, and temporal frequency. For some uses, fine spatial detail is crucial. In other cases, information is needed frequently, but does not require as much detail. For example, weather data are needed several times a day. Other times, having more measurements in the spectral domain provides the appropriate information. For example, when the health and vigor of plants throughout an entire region is desired, spectral coverage is important but spatial detail and some temporal frequency can be forfeited.

Applications of Remote Sensing

Some applications of remote sensing include evaluating spatial variability of soil and crop canopy surfaces for more efficient application of crop inputs. For example, we have used aerial photographs of bare soil surfaces (Figure 2) as a means of characterizing spatial variation in soil properties and their effect on corn yields. In this example, soil color data from the image was delineated, using computer-aided classification techniques, into management zones (Figure 2). A geo-referenced soil-sampling scheme was used to obtain field information about yield determining soil chemical properties (soil pH, EC, P, and organic matter). Soil chemical properties differed noticeably among the management zones (Table 2), with soil chemical properties being much more optimal for crop growth in the dark-colored soils of MZ 1 than the lighter colored soils of MZ 4. This was reflected in grain yield maps collected from this field, with higher yields located in MZ 1 and lower yields in MZ 4. These results indicate the potential value of using remotely sensed data as means of applying crop inputs.

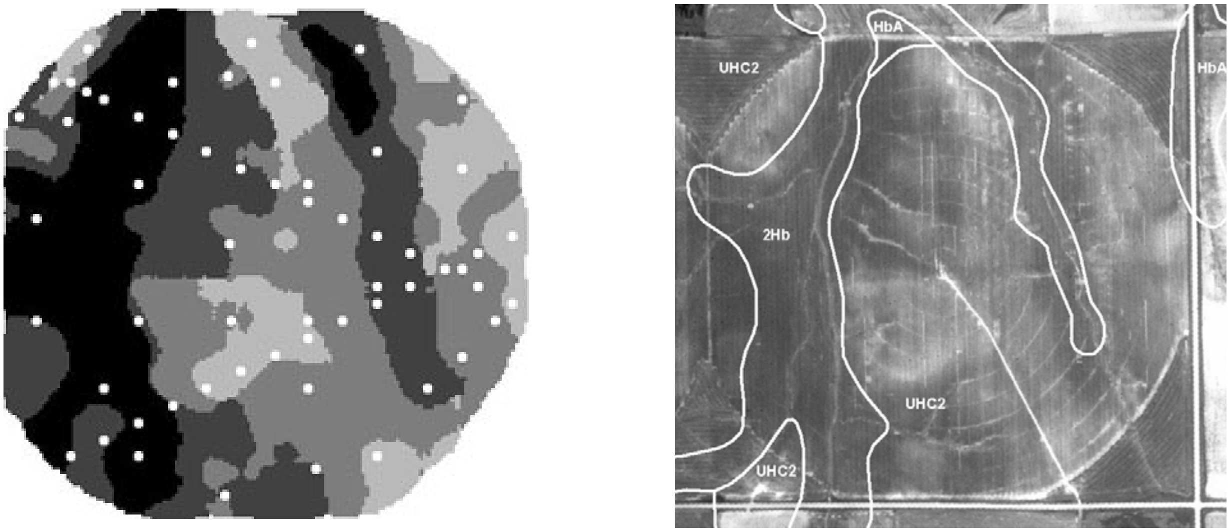

Figure 2. (Left) Bare soil aerial image of corn study site. Soil map symbols and boundaries are depicted for the Hobbs (2Hb) and Uly (HbA and UHC2) soil series, with Hobbs series consists of deep, medium-textured, well drained, nearly level to gently sloping soils formed in water-deposited silts, while the Uly series consists of deep, well-drained, medium-textured, moderately to strongly sloping soils. (Right) Gray scale map of management zones (MZ), resulting from unsupervised classification of soil color. MZ 1–MZ 4 are depicted with colors from dark to light. Georeferenced soil sampling scheme used to assess soil chemical properties overlain on to the MZ map.

Table 1. Soil pH, electrical conductivity (EC), phosphorus (P), and organic matter (OM) measured in the 0.3 m depth at the corn study site in the four mangement zones (MZ).

	Soil Attribute				
MZ	**number**	**pH**	**EC ($dS\ m^{-1}$)**	**P ($kg\ P\ ha^{-1}$)**	**OM ($g\ kg^{-1}$)**
1	12	6.41	0.28	71.7	14.2
2	16	6.48	0.30	35.9	13.8
3	19	6.64	0.33	20.1	11.5
4	12	7.43	0.42	9.4	9.5

Research Under Way in Our Group

Over-application of nitrogen (N) fertilizer on corn has resulted in elevated levels of N in ground and surface waters. A major factor contributing to decreased N use efficiency and environmental contamination for traditional corn N management schemes is routine pre-season application of large doses of N before the crop can effectively utilize this N. Our long-term research goal is to reduce these over-applications by using remote sensing to direct fertilizer only to areas needing N at times when the crop can most efficiently utilize the N.

We have assembled a prototype high-clearance tractor configured with red (red and NIR bands) and green (green and NIR bands) versions of the active Green Seeker sensors, drop nozzles with electronic valves, and a variable rate controller intended to deliver in-season variable rates of liquid N fertilizer based on crop needs (Figure 3).

Various small plot and on-farm strip trials were conducted in 2003 and 2004 to evaluate the various components of the high-clearance applicator and the response of corn grain yields to varying rates of N applied at different growth stages and across landscape spatial variability. Preliminary results indicated that the green version of the active sensor is more sensitive than the red version in detecting variation in canopy N status during the window we propose to apply N. Yield responses to N application were observed to vary across the landscape, and N responsiveness was more highly associated with variation in canopy reflectance assessed by the sensor than spatial variation in soil properties such as soil color. The objective of our future research is to verify recommendations on canopy reflectance thresholds for triggering in-season N applications by field testing sensor/applicator systems at a scale appropriate to farmers.

Figure 3. The high clearance N applicator (left) illustrating key components, including the active Green Seeker crop canopy sensor mounted on front. Both the red and green versions of the active sensor manufactured by Ntech Industries, Inc. (http://www.ntechindustries.com/) were tested and evaluated. The liquid N fertilizer delivery system (right), consists of two drop nozzles/valves placed at alternating rows of corn. Depending on the configuration of valves turned on/off, the system can deliver multiples of four (i.e., (0, 45, 90, 135 kg N/ha) rates of liquid N fertilizer on-the-go as directed by the controller system interfaced to the active sensor or with a prescription map.