Site-Specific Management Guidelines

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Potential Applications of Remote Sensing

Summary

Since the development of remote sensing nearly 60 years ago, there have been many applications for agriculture. Some have proved effective, while others have not succeeded in assisting farmers with problem solving. Profit margins for individual farmers are typically slim; therefore, farmers are likely to take seriously any technology advances that will help increase those margins. So far the use of remote sensing data has proven most economical for the high value crops where the risks are greater per acre. Remote sensing has not been perceived as cost-effective for Midwest crops where weather is the greatest variable and therefore not manageable. Recent advances in the spatial, spectral and temporal resolution of remote sensing (Johannsen et al., 1998) as well as potential positive changes in cost and availability of remotely sensed data may make it a profitable tool for more farmers. There are some practical applications of remote sensing that are often overlooked by many farmers and consultants. The purpose of this Guideline is to highlight those applications.

Soil Properties or Soil Inventory

Soil investigations, surveys and mapping are three types of applications using remote sensing information. They include three different approaches: the effects of soil properties on reflectance or image response, the influence of soil surface conditions on the response, and the use of imagery in mapping soil patterns. Satellite images such as Landsat Thematic Mapper (TM) data can be used in soil surveys for a broad range of applications. Soil spectral image responses are related to soil organic matter content in that the dark soils (higher organic matter) contrast to lighter soils (lower organic matter). The vegetation spectral response can also be used to infer various soil conditions. Yang and Anderson (1996) used these vegetation responses to define management zones within fields. The management zones are an aid to soil sampling as they define logical boundaries for obtaining samples. Remotely sensed images are also being used in "directed soil sampling" where one can map "soil management zones" which would be sampled as separate units. The management zones would become the basis for adjusting nutrient application rates using variable rate technologies (**Figure 1**).

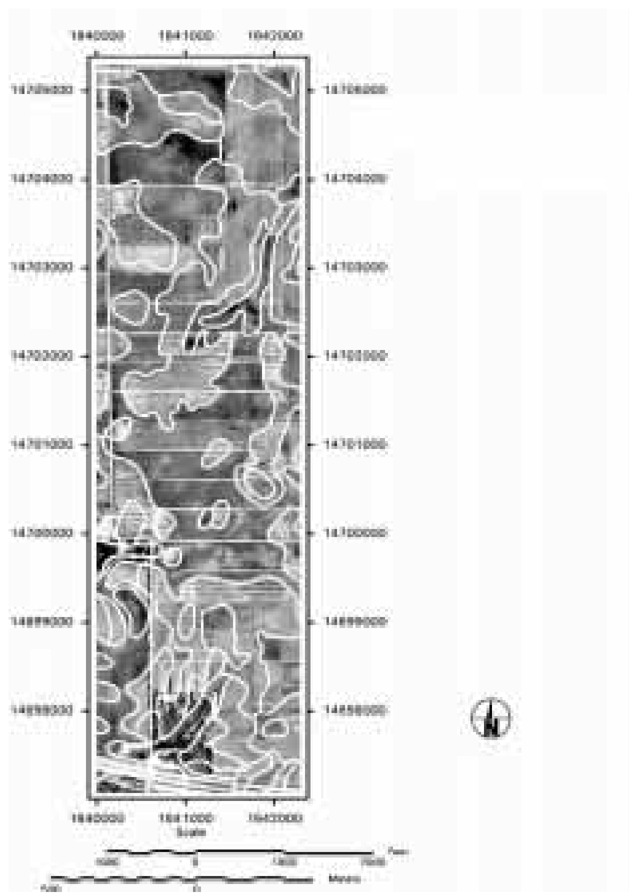

Figure 1. Soils delineated in white correspond well with patterns within the image.

Crop Inventory and Yield Prediction

At the regional and national scale, the USDA's National Agricultural Statistics Service (NASS) and the Foreign Agricultural Service (FAS) have explored the use of remotely sensed images for crop identification, inventory of areas planted and estimation of potential harvest

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amounts (Wade et al.). For grain crops, images near the time of flowering (i.e. tasseling in corn) are optimal for yield forecasting. Upon reaching this reproductive stage, most grain crops have completed their vegetative growth; therefore, yield influencing developments occurring after flowering may not be visible in the canopy. For other plants such as soybeans, more accurate yield predictions may be obtained later in the growing season due to continued vegetative development of the plants that reveal influences on yield. Current methods of yield prediction are often based on vegetation indices such as the Normalized Difference Vegetation Index (NDVI). These indices combine image information from near infrared and visible red bands in ratios of various forms. At the scale of farm and field, remotely sensed images have been used to give relative estimates of yield variation within a field prior to harvest. These compare well with actual yield maps (**Figure 2**).

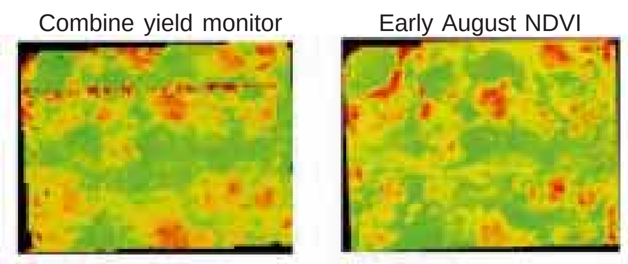

Figure 2. Comparison of yield monitor map and remotely sensed data.

The challenge remains at the farm level to develop more quantitative predictions of in-field yield variation and to deliver them in time to effectively influence crop management decisions. A predicted yield map at the time of corn tasseling, for example, would be too late to affect management decisions for the current crop.

Much research remains to obtain accurate yield prediction maps at the field level, because remote sensing measurements such as NDVI give only relative numbers that correspond to biomass (amount of vegetation) or other crop properties. These crop properties do not correlate perfectly to actual corn or soybean yields. A predicted yield map made through analysis of remotely sensed images could be used to help develop maps to guide variable application rates across a field. Integration of various remotely sensed images (soils and vegetation) with yield, plant tissue, and soil data into a geographic information system (GIS) will facilitate variable rate technology. There must be significant improvement in remote sensing capabilities before this can be fully realized.

Nutrient Detection

Using remote sensing information to detect field nutrient situations requires a thorough knowledge of what effects nutrient variations can have on the plant and on soils. Soil characteristics, such as color, relate to organic matter content from which one can predict nitrogen (N) release to the plant. Other soil properties such as pH, texture and nutrients such as phosphorus (P) and potassium (K) are difficult to detect. Leaf greenness is related to chlorophyll content, which is directly related to plant N concentration. Discoloration such as leaf chlorosis of the margins of leaves is correlated to K deficiency while purplish leaves are correlated with P deficiency. Most of the nutrient work in remote sensing has focused on N. There have been some encouraging results. For instance, leaf color measurements made at ground level have correlated well with corn plant N status (Blackmer et al., 1996).

Vegetation Change

Images from the green and near infrared bands highlight the amount of vegetation and give an indication of plant vigor. Some companies have been providing "crop vigor" maps to farmers to assist them in seeing where vegetative growth is occurring and to determine areas within the field were vegetation is not progressing as it should. Change detection can be accomplished by overlaying images from two flight dates and showing the vegetation change occurring between the two dates.

Detection of Crop Injury

Hail and wind damage is a common occurrence in many parts of the U.S., especially in the Midwest and Plains areas. Information about the amount of damage is useful to crop management and accuracy of insurance payments. For corn and soybeans, the greatest yield effects from hail or wind are usually related to leaf loss, stand loss, or lodging. In each case, the amount or orientation of leaves and stalks is altered and can be measured by remote sensing. Direct damage to the ears, pods or seeds is another component that is difficult to detect and measure directly. Images from non-damaged adjacent areas or before-storm condition would aid in the accuracy assessment. These images normally are color or color infrared. The use of color infrared film assists in the detection of damage areas. Color infrared gives a good indication of the amount or volume of vegetation or biomass present; therefore, lower values of red reflectance reveal vegetation damage or loss (**Figure 3**).

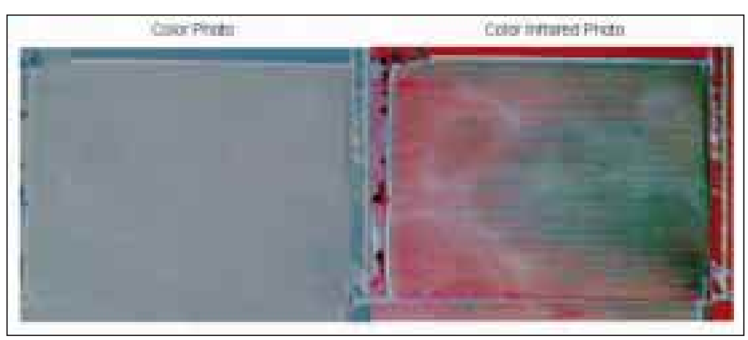

Figure 3. Color and color infrared photographs of the same soybean field. The right side of the field has been damaged by hail.

Crop Residue Evaluation

The FSA has established specific values for soil erodibility standards for given areas and requires that minimum levels of crop residue be maintained at the soil surface to reduce wind and water erosion. Remote sensing has proven to be a good method to manage supervision of those residue standards. Research has shown that different types of crop residue can be distinguished using Landsat TM images. Monitoring conservation tillage practices has been accomplished with the use of remotely sensed data at an acceptable accuracy.

Weather Data

The National Oceanic and Atmospheric Administration (NOAA) monitors the weather with the use of dedicated satellites and has become very accurate at short-range prediction of weather. Through these predictions, farmers are in a better position to manage many of their operations, such as hay production. In addition to aiding in weather prediction, satellite and ground radar data and can estimate weather variables such as precipitation for particular points (Petty et al., 1996), becoming virtual weather stations for a farmer's field. One example of how a farmer might access such data is a service offered by the EMERGE company. The service compiles information keyed to geographical location so that the farmer can acquire the weather data such as rainfall, growing degree days, minimum and maximum temperatures, etc. for each field or area (**Figure 4**).

Crop Stress

Crop stress includes anything occurring in the field different than what was planned. Some of the common crop stresses that can be measured are drought, weed patches, soil erosion, nutrient deficiency, and similar conditions. When trying to identify these types of stress using remote sensing, one can utilize some of the computer aided methods or simply use visual methods to discriminate. The ratio of the red to blue to the near-IR scene reflectance can indicate plant stress before it becomes evident on the ground. A vegetation index (brightness or greenness) is a reduction of several spectral bands into one "index" number. Emissions in the thermal IR band also can indicate plant health conditions. Other methods of detection may include change detection (subtraction of one image from an earlier image to see where the vegetation changed) and supervised or unsupervised vegetation classification (algorithms are used to select certain colored pixels and assign to a group). Identifying crop stress due to frost damage with the aid of Landsat TM images shows promise with the development of a modified NDVI (Jurgens, 1997). Methods have been developed to utilize color-infrared images to classify weeds in no-till cornfields (Brown and Steckler, 1995) and have been established to identify water stress in plants with the difference of remotely sensed surface temperatures and the measurement of ground based air temperatures (Jackson et al., 1981) (**Figure 5**).

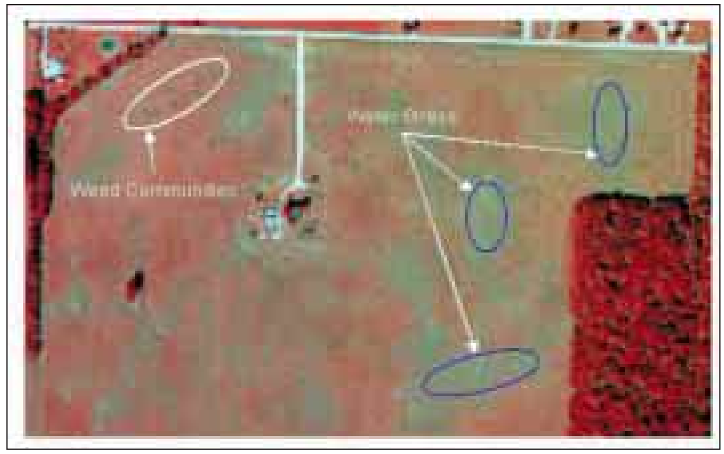

Figure 5. Examples of crop stress.

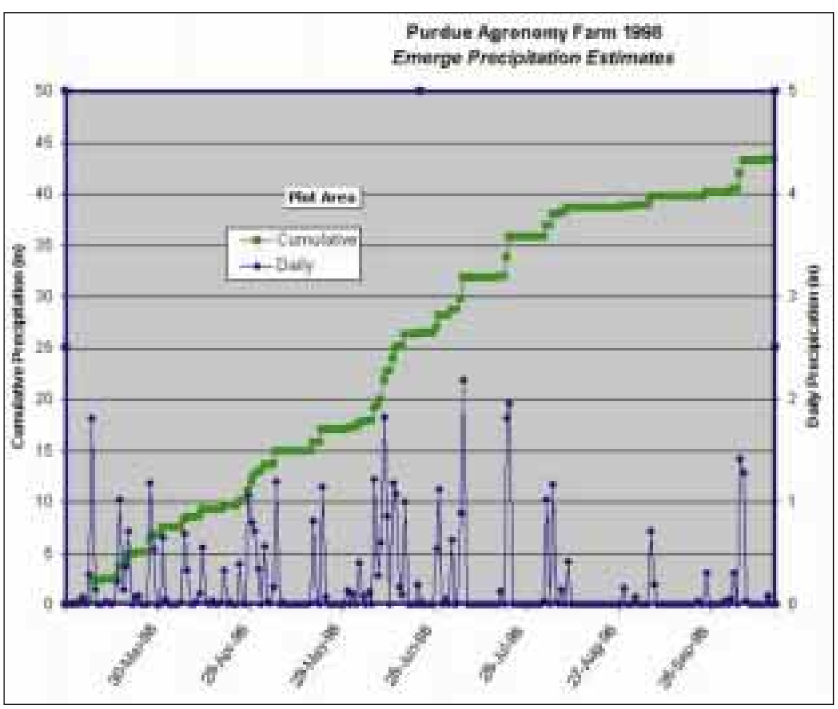

Figure 4. EMERGE precipitation estimates, 1998.

Land Use/Land Cover

One soon learns that remote sensers do not map land use, but map land cover and infer or interpret land use. This also means that land cover changes through the growing season. Therefore, land use will be mapped with varying accuracies on different dates. For purposes of using remotely sensed data on an individual farm, one doesn't need to spend time trying to achieve a high accuracy of identifying one crop from another since the farmer knows what was planted within the field. What becomes important is the ability to determine the variation in vegetative cover and understand the reason for this variation.

Regulation Compliance

The USDA Farm Services Agency (FSA), formerly the ASCS, has made use of aerial photography for many years as a means to verify compliance by land owners and farmers registered in the farm programs. Analysts at FSA use photography to measure the acreage of set-a-side or conservation reserve acres, determine locations of wetlands, verify conservation practices, and assist in disaster relief. This analysis would be very expensive to complete through typical ground visits. ■

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