

## 7.6 A Low-Cost Remote Sensing Platform for Agriculture

### Investigators:

Timothy Stombaugh, Assistant Extension Professor, Biosystems and Agricultural Engineering, [tstomb@bae.uky.edu](mailto:tstomb@bae.uky.edu)

Thomas G. Mueller, Assistant Professor, Agronomy, [mueller@pop.uky.edu](mailto:mueller@pop.uky.edu)

### Introduction:

In recent years, remote sensing (RS) has proven to be a potentially important tool for precision agriculture. In an agricultural context, remote sensing (RS) typically refers to any kind of imagery taken from above a field. Researchers have found many different ways that RS imagery can be used to aid management decision-making. Of particular interest are near infrared (NIR) images, which can be used to gain early recognition of crop performance or stresses.

Even though there is tremendous potential for RS in agriculture, images have not been easy to obtain. The primary sources for imagery have been satellite and aerial platforms. There are several different satellite-based systems that will provide imagery. Most satellite images are good quality and georeferenced so they can be loaded directly into GIS software. Unfortunately, most satellite systems have limited resolution, limited orbital periods, and they are adversely affected by cloud cover at the time of image acquisition. The combination of these limitations may prevent acquisition of an image at a desired time. Airplanes can be somewhat more flexible in scheduling than satellites, and they can operate below higher-level clouds. Depending on the imaging equipment, they can also have a very high resolution. However, professionally acquired aerial images are rather expensive, and there is often a time delay between when the image was taken and when it is actually made available to the producer.

Researchers at UK, recognizing the value of RS imagery and the challenges associated with acquiring the images, have developed a new RS platform based on unmanned aerial vehicles (UAV's). UAV's have been shown to alleviate many of the challenges associated with satellite and aerial platforms. The platforms

developed at UK are very inexpensive since they utilize readily available kit airplanes and common consumer-grade digital cameras.

One challenge with this low-cost imaging equipment is in calibration of the image data. Researchers discovered that the CCD sensing elements in most digital cameras are sensitive to NIR light. With the proper optical filters installed in front of the camera lens, many digital cameras can be used to obtain NIR images. Unfortunately, since the cameras are originally intended to record only visible light images, it is not clear how the NIR wavelengths are mapped to the data returned by the camera.

### **Objectives:**

The overall goal of this project is to develop a flexible, low-cost remote sensing system that can be used for agricultural applications. This goal will be met through the following specific objectives:

1. Develop a lightweight digital imaging system capable of obtaining high-resolution NIR images.
2. Calibrate the digital imaging device using commercially available sensor technologies.
3. Demonstrate the usefulness of the UAV imaging system for nitrogen management.
4. Demonstrate the utility of the UAV system for pre-scouting fields.

### **Background:**

To truly understand what a RS image is and what some of the limitations might be, one must first understand the concept of energy radiation and reflection. An imaging device, or camera, actually measures the radiation (light) energy that is coming from an object. Plants or soil do not actually create the light energy – they reflect the energy that comes from some source, namely the sun. Different plants will absorb certain wavelengths of light or allow them to pass through, while they reflect other wavelengths. A healthy, mid-season corn plant is very reflective of blue and green light making it appear dark green to the human eye. A post-senescent plant, on the other hand, will reflect more yellows and reds, making it appear brown. The key to using RS imagery lies in these reflectance properties of the plant – a healthy plant will reflect different wavelengths of light than will a stressed plant.

RS images are not restricted to visible light (wavelengths from 400-650 nm). In fact, near infrared (650 to about 1100 nm) can be much more powerful than visible radiation. Researchers have found that plants

reflect near infrared (NIR) radiation several times more intensely than visible radiation. We also know that the NIR reflectance of plants begins to change very quickly when a plant is stressed. This means that it is often possible to detect stressed areas in a field long before the human eye can begin to see evidence of stress.

There are many types of devices available for obtaining RS imagery. The most sophisticated devices are referred to as hyperspectral cameras. A hyperspectral camera will record the radiation intensity of narrow bands throughout the spectrum range of the camera. For instance, a camera may provide an intensity value for every 10 nm band over a range from 400 to 1000 nm, resulting in over 60 data values for each pixel in an image. Obviously, these devices provide very powerful information, but they are very expensive, and the images require tremendous amounts of memory and computing power for analysis.

A less sophisticated class of equipment is referred to as multispectral. Multispectral cameras record only a few (usually 3 or 4) bands of reflectance for each pixel. These devices can be obtained with a variety of bandwidths and configurations. In actuality, digital cameras can be considered multispectral because they record red, green and blue information. Most multispectral cameras will record at least one band of NIR information.

Though the term “remote sensing” is traditionally used to refer to whole-field imagery, technically, it can describe any type of sensor that measures a quantity without coming into physical contact with the plant. A variety of ground-based “remote” sensors have been developed to measure the spectral reflectance of plants. One advantage of using these sensors is that they can be used in real time control situations, such as to vary nitrogen application rate as the application machine moves through the field (Stone et al., 1995). They can also be configured as a handheld sensor to gather accurate information in localized areas. The disadvantage of ground-based sensors is that they cannot easily provide a complete field image. The user must traverse the field with the sensor while collecting sensor and position data and then construct a field map from that data.

There are a tremendous number research studies that could be cited to illustrate potential applications of RS for agriculture. To give a few illustrations, Thomasson et al. (2001) used RS images to determine soil properties. Yang et al. (2001) were able to monitor plant growth and health using RS images. GopalaPillai and Tian (1999) found strong relationships between RS data and crop yield.

One particular application where RS has great potential in Kentucky is in nitrogen management. A study in Kentucky, which was sponsored by NASA's AG 20/20 program, showed that RS could be used to measure nitrogen variability in wheat, but that more work is required to refine measurement and management strategies (Spectral Visions, 2001).

There are several other remote sensing projects underway at UK. Wells et al. (2001) are exploring the use of remote sensing to locate compacted areas in the field by looking at soil moisture variation. The project investigators are also involved in a newly funded project to develop a multi-faceted lens system for RS imaging devices (Menguc et al., 2002).

### **Procedures:**

***Objective 1: Develop a lightweight digital imaging system capable of obtaining high-resolution NIR images.***

A UAV platform for field image acquisition has already been developed (Fig. 1). This platform currently has the capability to carry a small low-resolution board camera and wireless video transmitter. The digital cameras that have been used to collect NIR



Figure 1. UAV remote sensing platform developed at UK.

images are too heavy for the aerial platform. There are two possible equipment options to obtain high-resolution images. The first option is to identify a small board camera with ample resolution for aerial field images. Unfortunately, these cameras are not readily available. The second option is to modify a digital camera to make it suitable for the aerial platform. Essentially, we need to eliminate components of the camera such as the flash, case, and LCD screen that are not needed in the aerial platform. Additionally, we need to design a fixture to fasten optical filters onto the camera lens. We will pursue this second option to develop a suitable imaging device.

**Objective 2: Calibrate the digital imaging device using commercially available sensor technologies.** Since the cameras that will be used in the aerial platform were not originally intended for NIR sensing, the data output will need to be calibrated. Our original intention was to use a high-quality multispectral camera to provide data to calibrate the aerial platform cameras. The problem with using multispectral cameras is that they are too heavy for small UAV's and must be carried in a full-sized aircraft. It is difficult to schedule these aircraft and get the equipment installed safely and legally. We will instead use a Hydro Agri FieldScan (tec5Hellma, Inc., Plainview, NY) ground-based multispectral sensor to obtain calibration data. The sensor will be installed on a tractor or high clearance vehicle and traversed through the field at the same time the aerial images are collected. The calibration will be performed with GIS software.

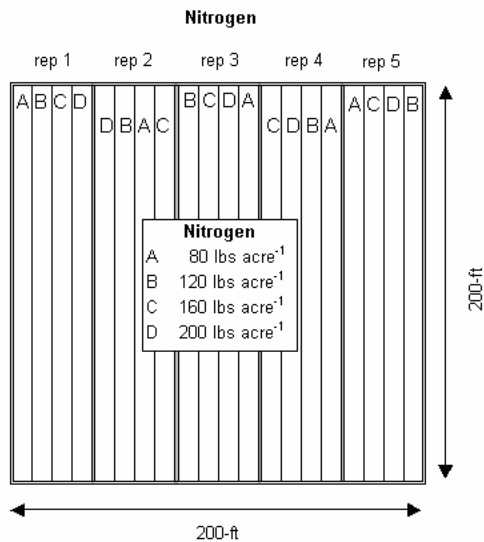


Figure 2. Experimental design for nitrogen application rate study

**Objective 3: Demonstrate the usefulness of the UAV imaging system for nitrogen**

**management.** The project investigators are currently pursuing another project, which was funded under a previous phase of this USDA special grant competition, to develop methods of detecting nutrient stress in corn and wheat. The experimental design (Fig. 2) will provide an excellent controlled area with various nitrogen concentrations to test the

UAV sensor. We will collect RS data using the UAV sensor several times throughout the growing season. Baseline data will be collected using the Hydro Agri FieldScan sensor and hand measurements that are already being collected as part of the nutrient stress study. These data will be used to verify the UAV data. The partnership between these two projects will increase the chance of success of the proposed project because of the availability of quality baseline data. The partnership will also strengthen the nutrient stress study since one

of the technologies that is being explored in that study is aerial multispectral imagery. The UAV data platform could provide an alternative method for collecting nutrient stress data.

***Objective 4: Demonstrate the utility of the UAV system for pre-scouting fields.*** One potential application of the UAV remote sensing platform is for pre-scouting fields. Essentially, a crop scout could use the UAV platform to obtain visible and/or NIR images of the field immediately before scouting. They can use these images to focus their efforts to areas of the fields where there may be problems or management opportunities. We will demonstrate the use of the platform for pre-scouting at field days and other extension events. In addition, we will initiate programs to promote the adoption of RS technology into management practices in Kentucky.

**Expected Benefits:**

The low-cost RS platform will provide a way for producers to obtain timely RS images that can be used for management decision making. It will also be a tremendous tool to aid in scouting fields for problem areas. The outreach programs initiated in Objective 4 will provide opportunities for producers to learn how to utilize RS data.

**Deliverables:**

We expect two refereed publications as a result of this project describing the imaging sensor equipment and the utility of the UAV platform for crop health measurement, as well as several related professional conference presentations. There will also be extension publications describing how producers could utilize RS imagery.