Multispectral Active and Passive Sensors in Agriculture

Introduction

Crop sensors are increasingly used to determine field variability in crop stands, detect wet spots in fields, predict yields, determine crop nutrient needs, and evaluate pest and weed control challenges. Crop sensors can be classified as active or passive sensor (Figure 1). Active sensors are used for close-up or proximal sensing of crops, and measure the amount of reflected light emitted by the sensor itself. Passive sensors measure the amount of light reflected from the sun. In this factsheet information on active and passive multispectral sensors will be provided.

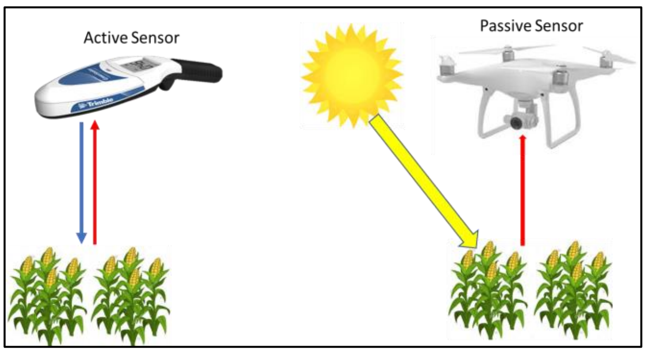

Figure 1: Active and passive sensors differ in the energy source used.

Vegetation Indices

Active and passive sensors measure reflected energy at specific wavelengths (visible, infrared, etc.). Some of these wavelengths (bands) are used to calculate vegetation indices. For example, the NDVI (Normalized Difference Vegetation Index) is calculated using near-infrared and red-light reflectance:

$$NDVI = (NIR-R)/(NIR+R)$$

The NDVI is useful because chlorophyll absorbs light in the red wavelength and healthy plants reflect less red light than stressed plants. Also, healthy leaves strongly reflect near-infrared light, based on their internal cell structures (Figure 2). Soil reflectance is lower than plant reflectance and so small plants or areas of less dense crop canopy will have lower NDVI readings.

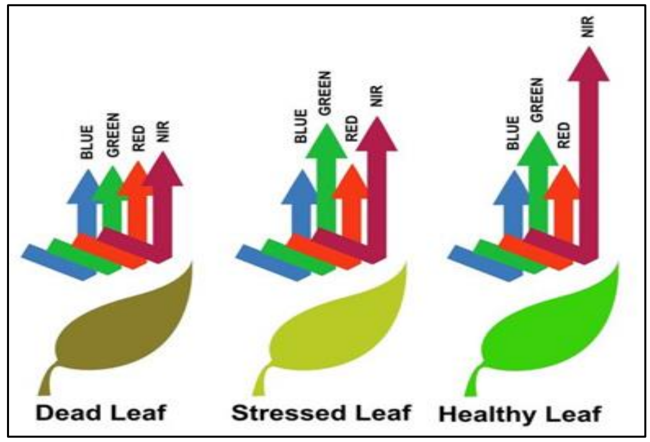

Figure 2: Light absorption and reflection of leaves (Source: http://www.zelmaerospace.com/precision-ag/).

While NDVI helps differentiate healthy plants (higher reading) from less healthy ones, it does not diagnose why a plant may be stressed or struggling. Crop varieties differ in color and soils differ in N supply potential and ability to cycle nutrients. Therefore, sensors used for N management require implementing an N-rich strip to ensure more N than needed in each field for comparison. The N-rich strip is used to determine within-field relative NDVI, which helps to identify N-stress from other forms of crop stress. See Agronomy Fact Sheet #89 for more information on N-rich strips.

Active Sensors

Examples of active sensors are Greenseeker, OptRx, and CropCircle. These sensors are typically mounted on tractors, sidedress, or spray units where applications are done right after sensing and NDVI calculation ("on-the-go"). It is important to follow scanning instructions carefully, such as distance over the crop canopy and correct crop growth stage.

An advantage of the use of active sensors is that the calculated NDVI is less affected by weather and light conditions than passive sensors. However, a disadvantage is that sensing can only be done as fast as the speed of the equipment that the sensor is mounted to. Hand-held units can also be used, but this becomes labor intensive.

Passive Sensors

Examples of passive sensors include cameras mounted on unmanned aerial vehicles (UAVs or drones), airplanes or satellites. As of now, they are mainly used to collect data regarding soil moisture, temperature, texture, and crop coverage and moisture. Passive sensors can cover larger areas in less time than active sensors that are mounted on tractors. However, data retrieval is more complicated; data must be uploaded, and pictures need to be patched or stitched together. Stitching images requires geometric processing, whereby images are properly located using their GPS location and a single image that contains the information of all the bands (called an orthomosaic) is generated.

As passive sensors use a natural light source, the light must be consistent to generate meaningful yield predictions or responsiveness to fertilizers. Cloud coverage, time of flight, and light angles affect the quality of the imagery (Figure 3). Thus, standardized protocols and region-specific algorithms need to be developed before images from passive sensors can be used consistently across fields on a farm, across multiple farms, and across regions.

Furthermore, flying of UAVs and planes require a specific pilot license, whereas use of active sensors does not require a license.

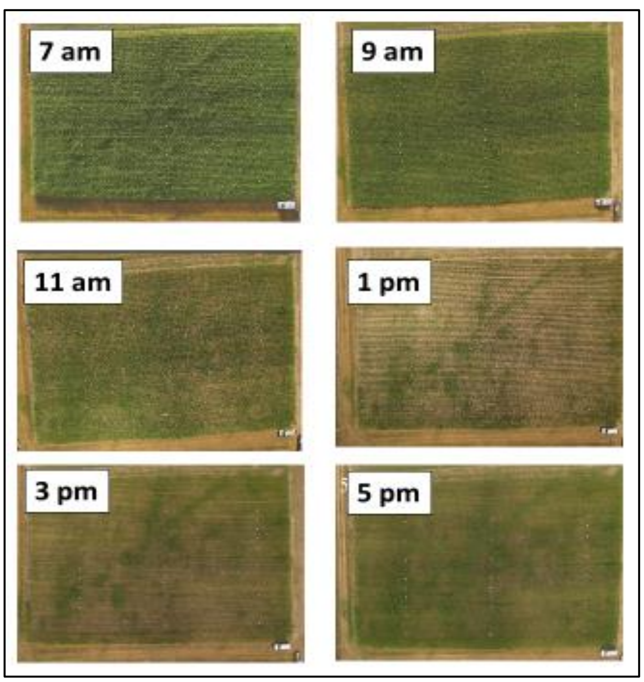

Figure 3: The timing of flight during the day can have a large impact of the images collected with drones. This is caused by varying sun elevation angles and intensity, as well as by changes in crop appearance itself. In this example, the drought caused corn plants to roll leaves during the hottest parts of the day.

Radiometric Calibration

Radiometric calibration involves the removal of the influence of illumination differences by using an in-field reflectance panel, which has known reflectance values for each band. Place this panel on the ground, avoiding any shadow, and sense it before and/or after each flight to adjust for and eliminate errors created by topography and atmospheric conditions. The relationship between spectral reflectance of the panel and the reflectance of the crop canopy is established through calibration of each flight. When properly done, this will result in data that can be compared across fields, farms, and time. Optimal conditions for the use of passive sensors are to fly within an hour of solar noon, and with clear sky (or uniform light conditions).

General Summary

Multispectral sensors can help with crop management and within-field decision making. Vegetation indices (such as NDVI) can be calculated using data from either active or passive sensors. Data from passive sensors will be impacted by weather conditions during scanning. Research is ongoing in New York to better predict corn and sorghum yield with data from active and from passive sensors.

Additional Resources

- Basics of Crop Sensing. Ortiz, B. J. Shaw, and J. Fulton. 2011. Alabama Cooperative Extension. ANR-1398. https://sites.aces.edu/group/crops/precisionag/Publications/Basics%20of%20Crops%20Sensing%20-%20Ext%20Pub%20ANR-1398.pdf
- Nutrient Management Spear Program Fact Sheet Series: http://nmsp.cals.cornell.edu/guidelines/factsheets.html

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For more information

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Nutrient Management Spear Program
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John Harvey, Quirine Ketterings, Karl Czymmek,
Angel Maresma, Jan van Aardt, Mike Contessa, Mike Hunter

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