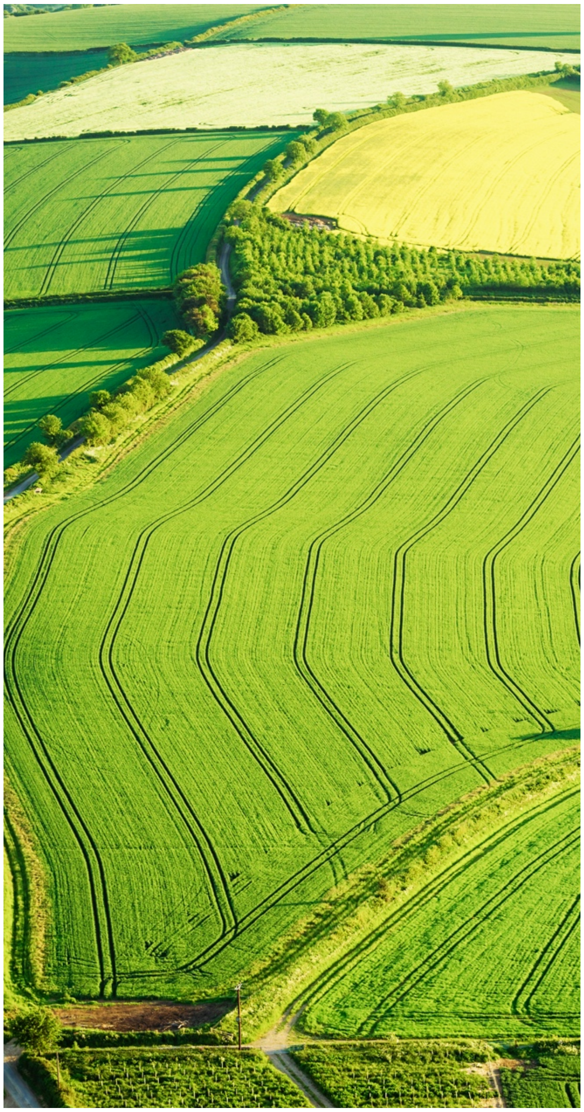


What agronomists, crop consultants, producers, and growers need to know before choosing a crop scouting sensor.

Collecting Accurate, Reliable Crop Health Measurements using Commercial Camera Sensors

sentera

By Ryan Nelson, Chief Mechanical Engineer for Sentera

Background

Unmanned aircraft (drones) have become a popular and effective tool for monitoring vegetation, analyzing crop health, and predicting yields. Within minutes, overhead imagery of fields can be collected and analyzed to provide actionable data to the grower. If the imagery is accurate and used properly, it can produce significant savings and increased yields for growers. However, with a large number of agriculture-related drone products on the market it can be difficult to compare capabilities and determine which systems provide the most accurate and reliable data. This study investigates a common deficiency of many of these drone systems and highlights what features should be sought when selecting a system or camera.

Vegetative Health Indices

In general, most agriculture drone cameras on the market offer a means to create a crop health index map using the photos that are taken by the camera. Most often, the index being displayed is the Normalized Difference Vegetation Index (NDVI) or Normalized Difference Red Edge (NDRE). These indices can be calculated by comparing the amount of light reflected by the crops in various regions of the light spectrum. The graph below shows how a typical plant will reflect light.

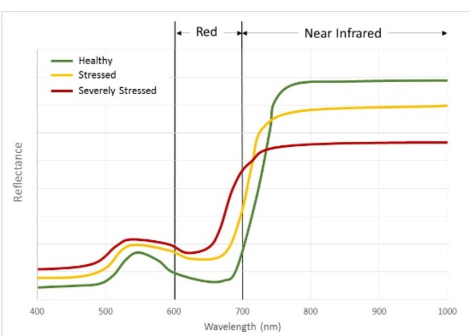


Figure 1 - Typical Vegetation Reflectance

NDVI, for example, compares the amount of light reflected in the red region (600-700nm) to the amount of light reflected in the near infrared (NIR) region (700-1000nm). Because healthy plants tend to reflect more NIR and absorb more red than unhealthy plants, a healthy plant will correspond to a higher NDVI value than an unhealthy plant. The formula for calculating NDVI is shown below.

NDVI = (NIR-Red) / (NIR + Red)

Commercial Sensors

So how do you get these NDVI measurements from the sensor found in a standard camera? Typically, sensors found in cell phone or point-and-shoot cameras are equipped with three channels for sensing colors. The channels are usually aligned to optimize photography of the visible spectral range (blue, green, and red) so that your photographs match what you see with your eye. NIR light is invisible to the human eye. While the sensors are capable of detecting light in the NIR range, that range is typically blocked using an optical filter. Otherwise, the NIR light would affect your pictures, making them look poor and washed out. The graph below shows a typical sensor response curve and the NIR range that is typically blocked.

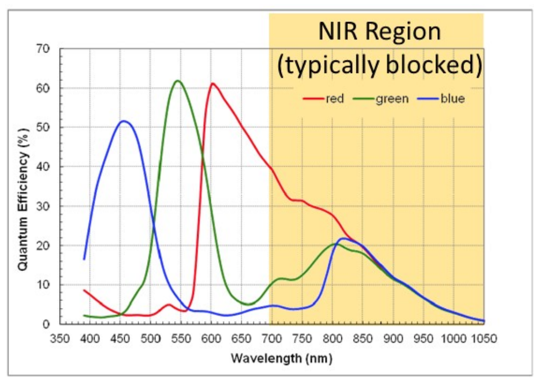
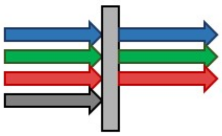


Figure 2 - Typical 3 Channel Sensor QE Curves

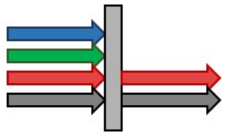
The blue, green, and red curves represent the sensitivity of the camera for the three color channels. All three channels have sensitivity in the NIR region, above 700nm.

Camera Modification

While most commercial cameras are not initially setup for measuring NIR emissions, they can be easily adapted by removing or replacing the optical filter that is blocking the NIR portion of the spectrum. In fact, this is the most common method for creating a camera that can be used to provide vegetation indices. For example, the NIR optical filter can be replaced with a longpass filter that allows only red and NIR emissions to pass.



Typical Camera Filtering
Passes Blue, Green, Red



NDVI Camera Filtering
Passes Red, NIR

This filtering technique would be useful for generating NDVI, which requires red and NIR.

Calculating NDVI

If the sensor shown in Figure 2 were paired with the filter described above, the resulting response curve would look approximately as shown in the graph below. In this graph, all emissions below 575nm have been blocked by the longpass filter and all emissions above 575nm are allowed to pass.

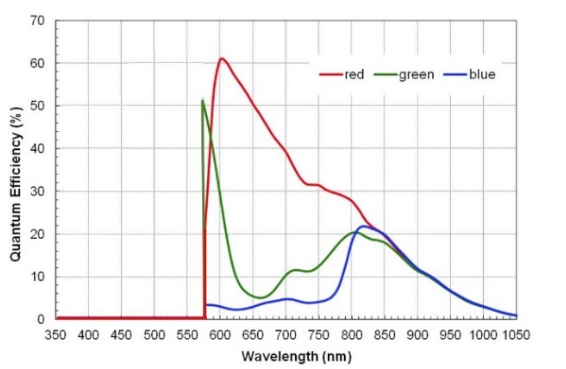


Figure 3 - Typical QE Curves with Longpass Filtering

Because all of the blue light, typically between 400nm and 500nm, is being blocked, most of what the blue channel is sensing is actually NIR light. In this case, the blue channel is most sensitive between 800nm and 900nm. Therefore, the blue channel can be used as a reasonable approximation for the NIR content of whatever is being photographed. The red channel, on the other hand, is sensitive in both the red and NIR regions. In order to approximate the red content of the photo, it is common to simply subtract the blue channel from the red channel. The area highlighted in pink in the graph below represents the portion of the red channel that would be remaining after the blue channel is subtracted out.

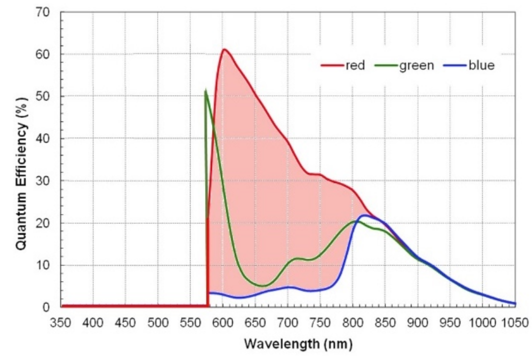


Figure 4 - NDVI Red Channel Content

Error Sources

When attempting to calculate the NDVI index it is in your best interest to ensure the light content is as accurate as possible. When looking at the graph above it is apparent that not all of the pink area is truly comprised of “red” light. As mentioned earlier, the red region of the spectrum typically ranges from approximately 600nm to 700nm. In the graph above, a sizable portion of the pink area is above 700nm and therefore not truly red but rather NIR. This will reduce the accuracy of your NDVI measurement.

However, the problem is even worse than it appears as first glance. The plot below shows the same response curve of the camera, only we have highlighted in red the region that is within the “red” spectrum. We’ve highlighted in pink the region that is falsely being assumed as red.

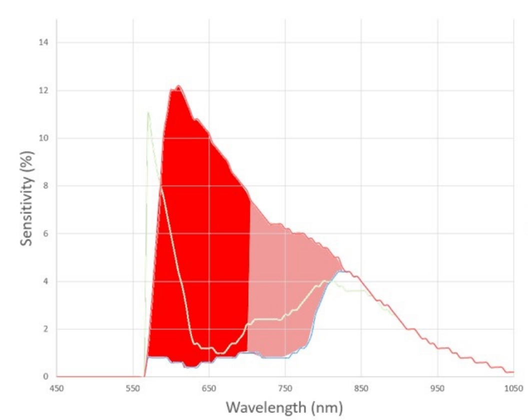


Figure 5 - Red and NIR Portions of Red Channel

Initially, this does not appear overly significant. The pink region comprises perhaps one third of the total combined area of the two. The red channel is still mostly comprised of truly red content and therefore a reasonable approximation of red. However, as was mentioned earlier we must keep in mind that vegetation is much more reflective in the NIR region beginning above 700nm than it is in the red region. In other words, when light reflects off of typical vegetation, more NIR light will leak into the sensor's red channel, corrupting the measurement. The graph below shows the response curve after correcting for the reflectance of vegetation. The pink area in the graph shows how significantly undesirable red channel leakage impacts a basic NDVI imager in typical agriculture applications.

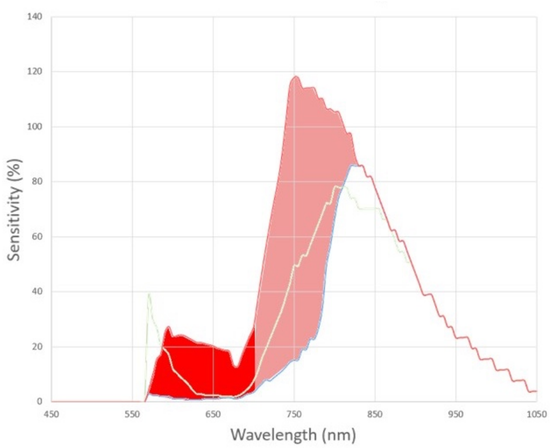
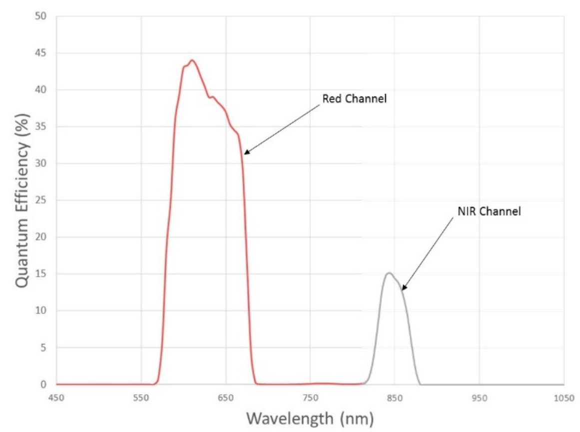


Figure 6 - Red and NIR Portions of Red Channel after Reflectance Correction

As shown, when taking photographs of vegetation this calculation for estimating red will result in the majority of the red content being comprised of NIR light. In fact, for this typical sensor, 75% of the red content is coming from sources that are not within the red spectrum. This amount of contamination of the red data will negatively affect the accuracy and reliability of the NDVI measurements taken from the camera.

Sentera Precision Filtering

Using advanced filtering techniques, Sentera is able to eliminate the sources of error described in the previous sections. Specifically, in addition to blocking all emissions below 575nm, Sentera NDVI sensors also block all emissions between 675nm and 830nm, eliminating any contamination from the range between red and NIR. The resulting spectral response curve is shown below.



As shown, this filtering approach provides two extremely precise, narrow bands for red and NIR. The only sensed emissions in the red band are truly red, between 575nm and 675nm. Further, all emissions sensed in the NIR band are true NIR, between 830nm and 850nm. This means you are getting the most accurate and reliable NDVI data possible.

Summary

This study illustrates that not all agriculture sensors are equal. Without proper investigation, you could end up with a system that provides unreliable and inaccurate vegetative health information. Using a Sentera sensor with advanced filtering you can be confident that the data you're collecting is accurate and is giving you the best possible vegetation indices, therefore allowing you to be more effective in determining and responding to the overall health of your plants.

ABOUT SENTERA
With over 220 years of combined experience with sensors, software, and drone system development, Sentera is a leading supplier of complete data solutions to the agriculture industry, making it easy for users to bring in-field data off the farm for further analysis. For more information, visit www.sentera.com