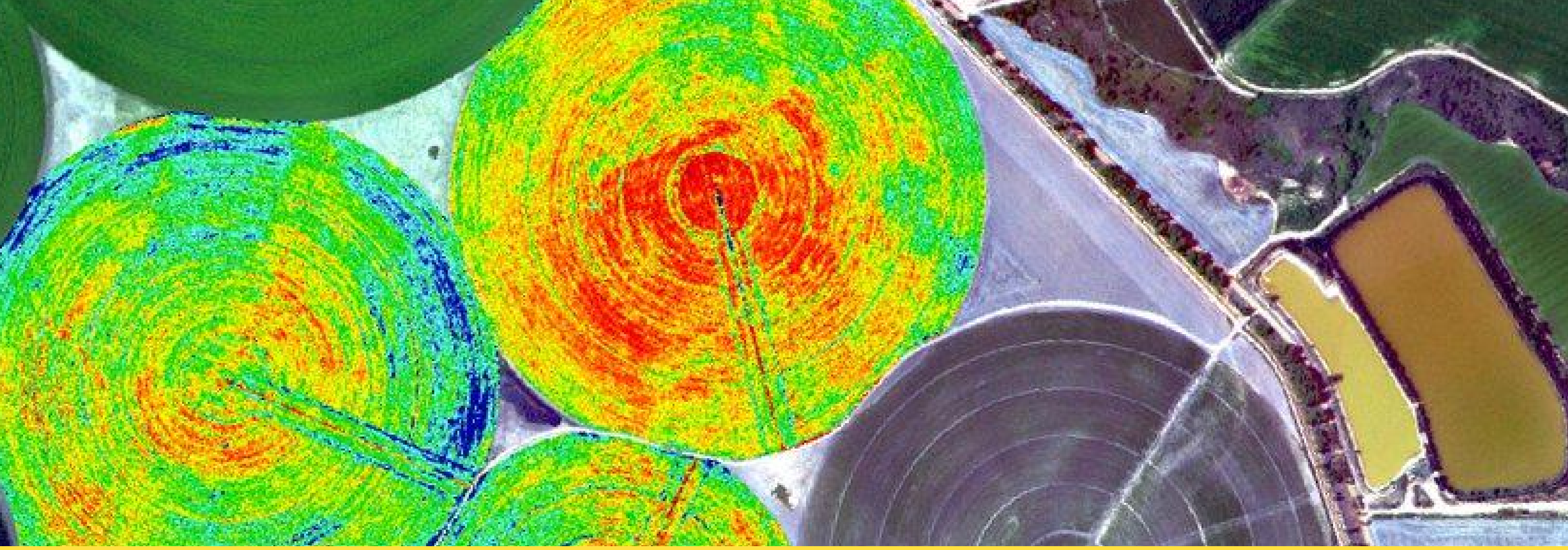

# Hyperspectral Remote Sensing for Agriculture

Image Courtesy: www.specterra.com.au

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Advanced analysis of natural resources particularly crops and soil requires high spatial and spectral resolution data to increase producers' sustainability and environmental protection. The studies pertaining to crop growth requires assessment and quantification of biochemical and biophysical attributes. More better spatial resolution cannot provide satisfactory analysis results because of limited number of wavebands in multispectral data. The multispectral broadband-based remote sensing is not capable of providing accurate quantitative estimates of biochemical properties because of low spectral resolution. This limitation of multispectral remote sensing data led to the concept of hyperspectral remote sensing particularly imaging spectroscopy. The hyperspectral remote sensing data comes with hundreds of narrowly defined contiguous bands and offers very minute details about plant biochemical and biophysical attributes related to its health through various spectral regions. For instance, changes in chlorophyll a and b is characterised by early wavebands in 350 to 2500 nm range data.

## Spectral Properties of Vegetation

The hyperspectral remote sensing data can be acquired through field based spectroradiometers, satellite borne sensors or airborne sensors. The spectroradiometers are very useful instruments in agriculture related studies. Fig-1 Shows a typical vegetation spectrum of reflectance for rice crop recorded by ASD field spec-3 spectroradiometer. It records the reflectance of the objects in 350 to 2500 nm wavelength region with 1 nm interval. Using this reflectance spectrum data for crops and soils, very useful studies can be executed. The vegetation spectrum (Figure 1) shows the regions of absorption for water, chlorophyll, etc. The visible (VIS) region of spectrum is mostly used for chlorophyll a and b related studies. The near infrared (NIR) region is governed by cell structure of plants and the short wave infra red (SWIR) region shows the absorption troughs for water and also have reflective properties for leaf biochemical parameters like protein, lignin and cellulose, etc. The region between 690-740 nm is called red edge position where the reflectance changes from very low in the chlorophyll red absorption region to very high in the near infrared because of leaf and canopy scattering. This region is found to be sensitive to total canopy chlorophyll by many researchers. This region is also an indicator of water stress in plants. Besides the spectroradiometer data, the Hyperion sensor is also a source of satellite borne hyperspectral data. Figure 2 shows the spectral reflectance profiles of various features extracted from Hyperion data.

Many airborne hyperspectral sensors are also available like Airborne visible/infrared imaging spectrometer (AVIRIS) and Compact Airborne Spectrographic Imager (CASI), etc that provide high spectral and spatial resolution, high temporal resolution and precise ground coverage with high geo-location accuracy. Figure 3 and Figure 4 shows spectral responses of crop plants due to change in biophysical parameters i.e. relative water content and chlorophyll respectively. These figures present the sensitivity analysis for relative water content (RWC) and chlorophyll a & b (Cab) in crop plants.

## Hyperspectral Remote Sensing Data Analysis for Agricultural Crops

Hyperspectral remote sensing provides many ways to analyse the crop health, to develop prediction models for crop health parameters as well as modelling for monitoring of timely water deficit stress in crop etc. The basic analysis on a hyperspectral data can be done using spectral indices (ratio of 2 or more bands).

Hyperspectral data comes in narrow contiguous bands, therefore minute changes related to a parameter of interest can be observed and the most optimum wavebands for that parameter can be extracted for prediction model development. This prediction model may be useful for future assessment of that parameter. The most sensitive/ optimum bands related to a important parameters of crop can be detected using various approaches like lambda by lambda plotting, multivariate modelling techniques i.e. PCA, PLSR, MLR, SVMR, RF MARS etc., wavelet analysis and artificial neural networks. The lambda by lambda plotting is useful for development of a new effective hyperspectral index. For instance, The vegetation water content which is a vital biophysical parameter of plants need to be monitored at precise timings because lack of water content in plants will lead to low yield of crop. The reflectance data of the target crop and simultaneously measured any parameter of crop related to water content can be used to develop a new hyperspectral index (ratio index or normalized difference index) for assessment of water content and a prediction model can also be developed for timely identification of water status in crop. The radiative transfer modelling approach (e.g. - PROSAIL model) is also used by many researchers to retrieve the vegetation parameters for monitoring of crop health status.

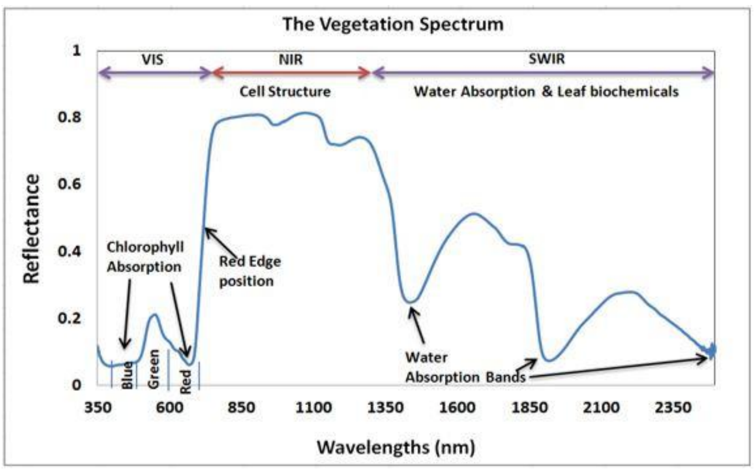


**Figure 1. The typical vegetation reflectance spectrum of rice crop in 350 nm to 2500nm range showing details**

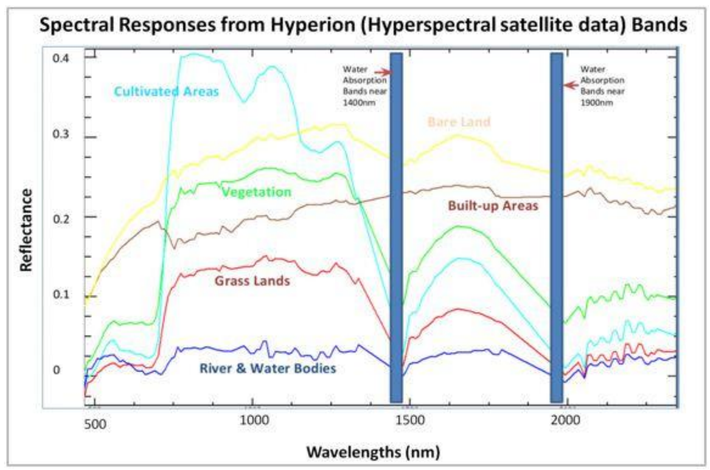


**Figure 2. The spectral reflectance profiles of various features extracted from Hyperion satellite imagery.**

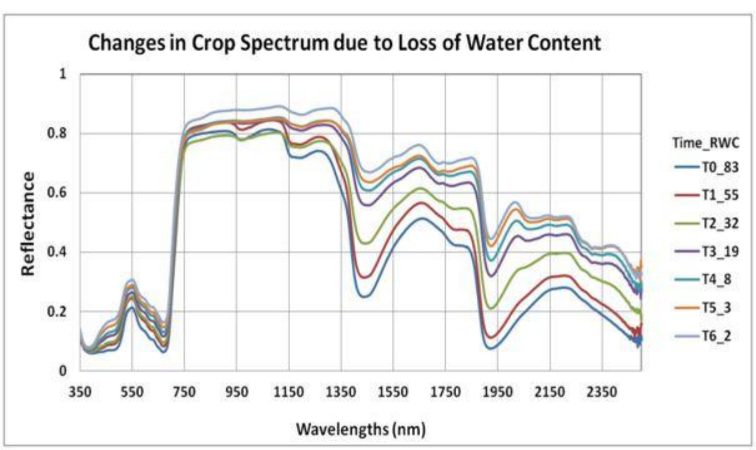


**Figure 3. Changes in reflectance spectrum of crop due to water deficit stress. With loss of water content, spectra in SWIR region goes higher because SWIR region is dominated by water content in leaves**

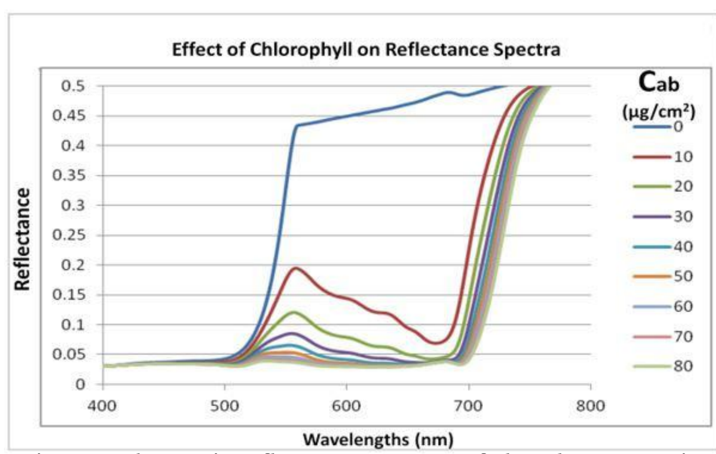


**Figure 4. Changes in reflectance spectrum of plant due to quantity of chlorophyll. Higher the chlorophyll, lower the reflectance**

There are many other areas where hyperspectral data can be utilized in agriculture. The most common applications where hyperspectral remote sensing data is extensively used are early detection & diagnostics of plant diseases, weeds & pests; prediction of yield & crop growth monitoring; nutrient deficiency diagnostics & stress detection; and crop variety discrimination. Early detection of diseases in plants enables quick and targeted responses.

The yield prediction provides policy makers to get insights of the production in a region and thus enables to take an effective decision. The timely detection of environment stresses such as extreme temperature, nutrient deficiency and water shortage in crops enables the precise prescription of required quantity of macronutrients i.e. Nitrogen, Phosphorus and Potassium (N, P, K). Remote sensing's wide area coverage and hyperspectral data's rich spectral resolution helps greatly to monitor these environmental stresses.

In a nutshell, the hyperspectral remote sensing data has ample capability to provide satisfactory analysis results for monitoring health of the crops. This enables effective decision making for the farmers and policy makers.

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> "Hyperspectral sensor is capable of acquiring data well beyond the spectral range of a multispectral sensor, every pixel in the image thus contains a continuous (in radiance or reflectance) spectrum and enables critical insight for scalable, very high spectral-resolution vegetation monitoring in several key ways... this increased spectral-resolution is used to make accurate machine learning models of crops.