

DETECTION OF TRACE QUANTITIES OF GREEN VEGETATION IN 1989 AVIRIS DATA

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ABSTRACT

AVIRIS data acquired on September 20, 1989 were calibrated to ground reflectance and used to determine the detection limits for green vegetation. The chlorophyll red edge was detected in Monterey Pine plots having green vegetation covers as low as 3.8%.

INTRODUCTION

The detection of trace quantities (less than 10% cover) of green vegetation using remotely sensed data continues to be problematic. A series of red versus near infrared (NIR) vegetation indices has been used routinely on data from broadband sensors (e.g., Tucker, 1979). The red versus NIR vegetation indices operate by contrasting the chlorophyll pigment absorption in the red with the high reflectance of green leaves in the NIR. Under low green canopy cover conditions background rock and soil materials produce a range of vegetation index values, degrading the accuracy of broad band vegetation indices (Elvidge and Lyon, 1985).

The advent of high spectral resolution remote sensing opens up the possibility of extending the detection limits for green vegetation. The chlorophyll red edge (Collins, 1978), located from 700 to 780 nm is the sharpest spectral feature of green vegetation. This spectral feature is absent in rocks and soils. Our hypothesis is that the chlorophyll red edge will be the most persistent spectral feature of green vegetation at low levels of canopy cover. Elvidge and Mouat (1989) report detection limits near 2% cover using the chlorophyll red edge feature in 1988 AVIRIS data. This paper repeats the experiment described by Elvidge and Mouat (1989) using data acquired in 1989 by NASA's Airborne Visible-Infrared Imaging Spectrometer (AVIRIS).

DATA ACQUISITION AND ANALYSIS

A flight line was selected in 1987 to provide AVIRIS data of Stanford University's Jasper Ridge Biological Preserve plus a series of calibration targets. AVIRIS data for this investigation was acquired on September 20, 1989 at 1:58 PM Pacific Standard Time. Radiometrically corrected data were calibrated to ground reflectance using a set of four calibration targets of known reflectance: 1) a black rubber running track at Canada College, 2) the outer parking lot (asphalt) at Canada College, 3) Humpheries Polo Field, and 4) open water from Searsville Lake. These targets cover a spread in ground reflectance from 0 to 40% over the AVIRIS bands. Linear regression was used to generate equations for converting AVIRIS digital number (DN) values into percent ground reflectance (Elvidge, 1988). The regression results are presented in Figure 1. Application of the equations removes the influence of solar illumination, most atmospheric effects (attenuation and scatter), and uncorrected band-to-band instrument response functions from the data.

The Jasper Ridge flight line covers a commercially operated Monterey Pine (Pinus radiata) plantation (a Christmas tree ranch) located on the strip of land between Sand Hill Road and the Stanford Linear Accelerator (SLAC). The pine trees are planted in rows and the interrow areas have been cultivated to remove unwanted plants (weeds). Various age stands are present, producing several levels of green vegetation cover. Pixels from a series of plots were extracted from the AVIRIS data and converted to units of ground reflectance. The percent green cover in each plot was determined using low altitude aerial photography. The photography was digitized and then analyzed with a supervised classification to determine the percentage of green vegetation cover. Table 1 summarizes the number of pixels and percent green vegetation cover for the five plots.

TABLE 1

	Number Of Pixels	Percent Green Cover
PLOT 1	16	21.9%
PLOT 2	12	20.0%
PLOT 3	24	12.8%
PLOT 4	20	11.6%
PLOT 5	9	9.6%
PLOT 6	32	7.8%
PLOT 7	20	5.0%
PLOT 8	16	3.8%
PLOT 9	6	2.2%
ASPHALT	42	0.0%
WET SOIL	8	0.0%

Jasper Ridge-AVIRIS Calibration
September 20, 1989

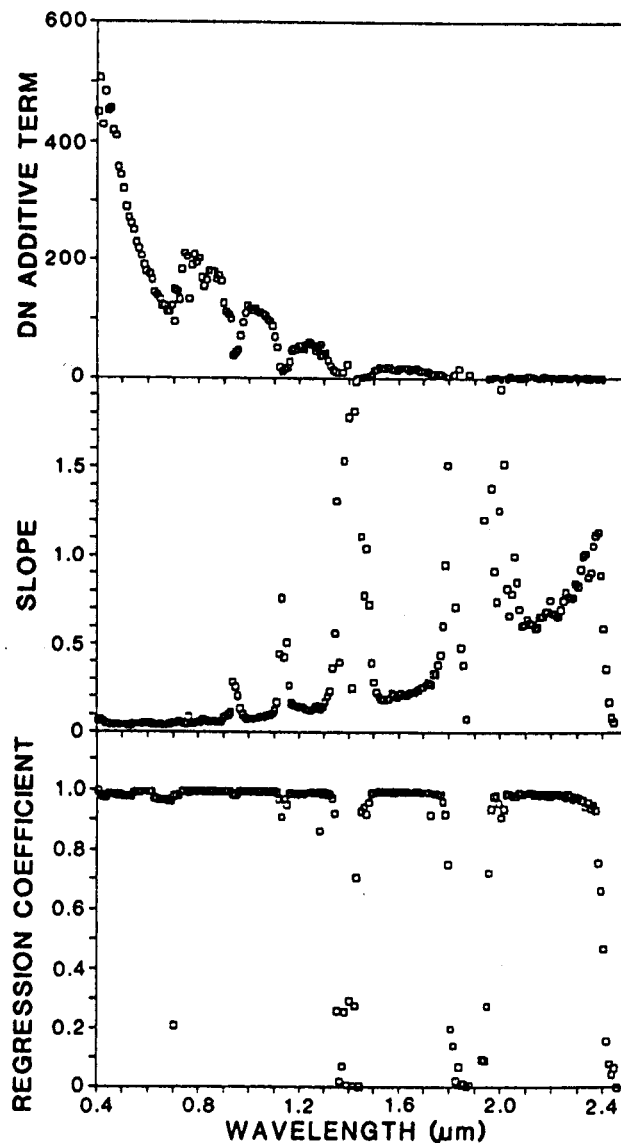


Figure 1. Results from the digital number to ground reflectance linear regressions. The regression coefficients (R^2 values) versus wavelength are presented in the lower segment. Equations were formed only for bands yielding R^2 values of 0.8 or better. The middle panel shows the slopes (B term) determined for the equation: Reflectance = $A + B \cdot \text{DN}$. The upper panel shows the "DN additive term" (DN intercept for zero reflectance) versus wavelength. The "DN additive term" encapsulates the additive factors of atmospheric path radiance and uncorrected instrument dark current.

RESULTS

The AVIRIS reflectance spectra for the Monterey Pine plots from 400 to 900 nm are shown in Figures 2 and 3. Figure 2 shows the spectra derived from plots with more than 9% green cover while Figure 3 shows the spectra for plots with 0 to 8% green cover. The curves were developed by taking the mean DN data for the group of pixels extracted from a plot and converting to ground reflectance using the equations developed in the calibration procedure. The curves for plots with 20 to 21.8% green cover exhibit recognizable spectral features of green vegetation, including chlorophyll pigment absorption in the red at 683 nm, a chlorophyll red edge from 700 to 780 nm, and high reflectance on the NIR plateau (780 to 900 nm). These features are also present, in subdued form, in the AVIRIS reflectance spectra of plots having 9.6 to 12.8% green cover on Figure 2 and plots having 7.8, 5.0, and 3.8% green cover on Figure 3. The vertical lines on Figures 2 and 3 at 683 and 723 nm mark the positions of the chlorophyll pigment absorption and red edge shoulder in the plots having less than 15% green cover. These features persist in plots having 5.0 and 3.8% green cover, but are not clearly expressed in the spectrum derived from a plot having 2.2% green cover (Figure 3). Surfaces having zero green cover (asphalt and wet soil) lack the chlorophyll pigment and red edge features.

CONCLUSION

Spectral features associated with chlorophyll pigment absorption in the red, and the chlorophyll red edge can be readily detected in AVIRIS data at green vegetation covers of greater than 10%. Traces of these spectral features persist in AVIRIS reflectance spectra down to green vegetation cover levels of 3.8%. This capability exceeds the detection limits for green vegetation obtained for broadband sensors.

There are several reasons why these two spectral features are useful for detecting trace quantities of green vegetation: 1) The chlorophyll red edge is the sharpest spectral feature of green leaves. That is to say, it is the region with the greatest change in reflectance over the smallest change in wavelength. 2) There are no other natural materials yielding an absorption edge of similar magnitude in the same spectral position. 3) There is good solar illumination from 0.7 to 0.8 μm . While the wavelength position of the chlorophyll red edge may not be measurable at low green vegetation covers, the presence and magnitude of the chlorophyll red edge may prove to be of great value in detecting and quantifying trace quantities of green vegetation.

AVIRIS REFLECTANCE DATA

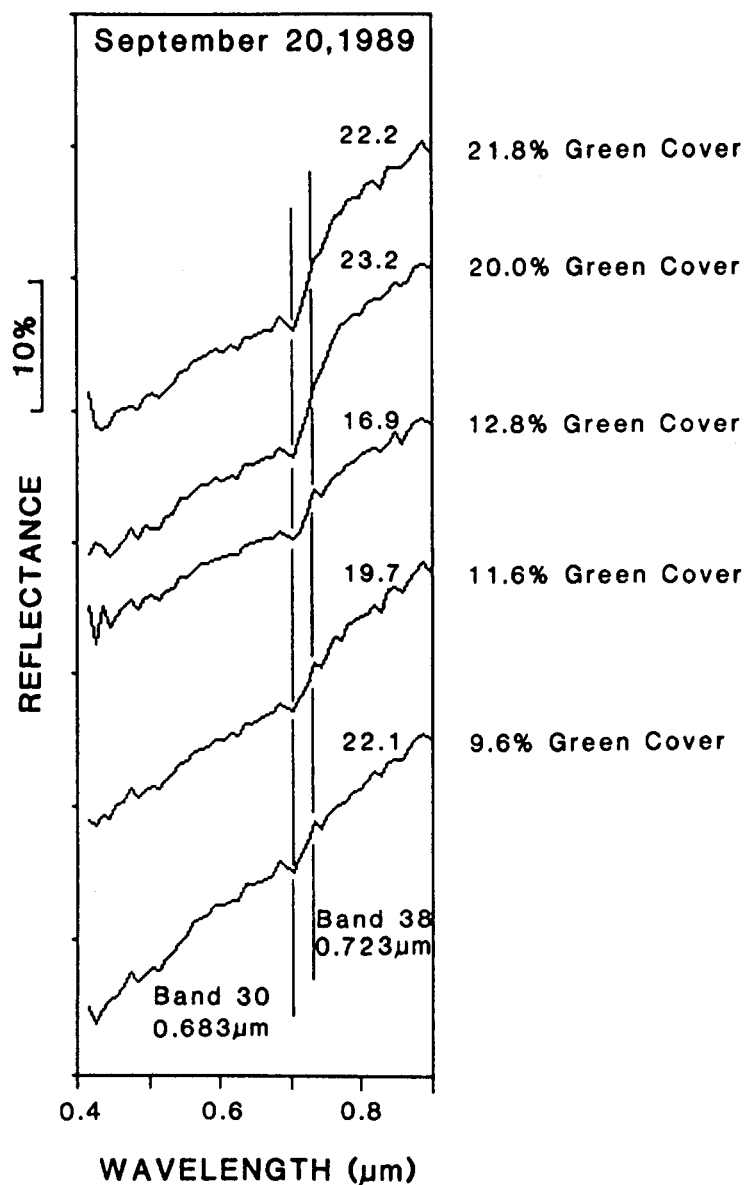


Figure 2. AVIRIS reflectance spectra for the five plots of Monterey Pine ranging from 9.6 to 21.8% green cover. The curves have been offset vertically to avoid overlap. The reflectance at 800 nm is provided for each spectrum.

AVIRIS REFLECTANCE DATA

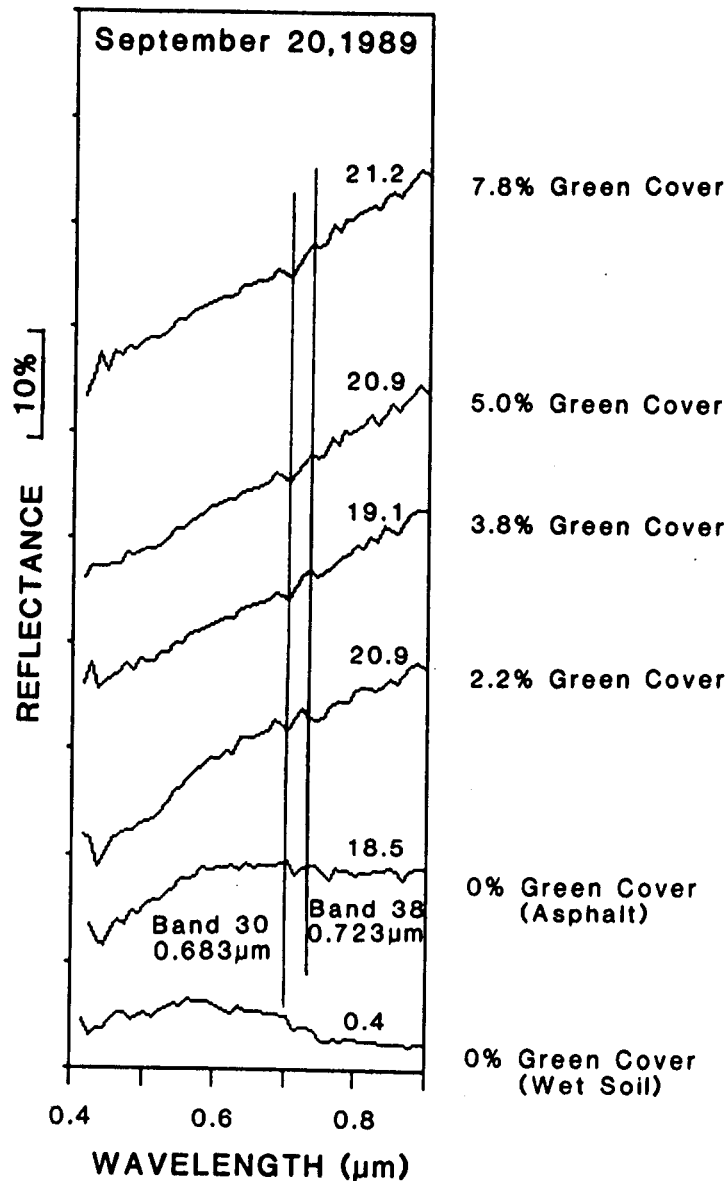


Figure 3. AVIRIS reflectance spectra for the five plots of Monterey Pine ranging from 9.6 to 21.8 % green cover. The curves have been offset vertically to avoid overlap. The reflectance at 800 nm is provided for each spectrum.

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