DETECTION OF TRACE QUANTITIES OF GREEN VEGETATION IN AVIRIS DATA

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ABSTRACT. The reflectance of an annual grassland area was tracked from spring through early summer and early fall using three dates of ground-reflectance calibrated AVIRIS data sets acquired in 1989. The grassland exhibited green vegetation spectral features in the spring. The dominant annual grasses were senesced in early summer and early fall imagery, though the site still had trace quantities of green herbaceous vegetation present. The chlorophyll red edge, from 700 to 730 um, is still present in the dry grassland spectra. This red edge, and the green vegetation it represents, would not have been detected with data from broadband sensors.

I. 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 have been developed for use on data from multispectral instruments such as SPOT, Landsat Thematic Mapper, and NOAA AVHRR (Tucker, 1979). The red versus NIR vegetation indices operate by contrasting the magnitude of chlorophyll pigment absorptions in the red with the high reflectance of green leaves in the NIR. These broad band vegetation indices have not been effective under low green canopy cover conditions because background materials (rocks, soils, litter, and senesced plant materials) produce a range of vegetation index values (Elvidge and Lyon, 1985; Elvidge, 1990).

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) is the most prominent spectral feature of vegetation in the visible and near infrared region. The sharp definition of the chlorophyll red edge makes it an ideal feature to consider for use in detecting trace quantities of green vegetation. The detection and measurement of the chlorophyll red edge require high spectral resolution. Broad band sensors, such as SPOT or Thematic Mapper, are unable to directly measure this spectral feature.

Using 1988 and 1989 AVIRIS data converted to units of ground reflectance, the authors (Elvidge and Mouat, 1989; Elvidge et al., 1990) determined that the chlorophyll red edge persisted to levels of green vegetation covers of 3.0 to 5.0% for plantation grown pine trees. In this paper we report the results obtained from AVIRIS data extracted from an annual grassland on three dates in 1989, spanning spring, summer, and fall phenological conditions.

II. STUDY SITE

An AVIRIS flight line over Stanford University's 1200 acre Jasper Ridge Biological Preserve was established in 1987. In addition to Jasper Ridge, this flight line is designed to provide AVIRIS data of a series of calibration targets.

Jasper Ridge is located west of the main Stanford campus, in the foothills of the Santa Cruz Mountains. The preserve contains examples of the primary plant communities of the central California coast. Jasper Ridge has been the site of biological investigations for more than 90 years and has numerous ongoing ecological and physiological studies. The plant community used in this study is the annual grassland present on top of the ridge. A low altitude aerial photograph of the grassland is shown in Figure 1 (Slide 17). The species in this area are largely annuals, with introduced grasses making up the bulk of the biomass. The species present include: Wild Oat (Avena fatua), Slender Wild Oat (A. barbata), Soft Chess (Bromus mollis), Ripgut Grass (B. rigidus), and Tarweed (Madia sativa). In some portions of the grassland there is an encroachment of a perennial shrub known as Coyote bush (Baccharis pilarus).

The climate at Jasper Ridge is described as Mediterranean, with cool temperatures and the largest portion of the precipitation occurring as winter rains. Precipitation is variable but averages 60 to 75 cm per year. Summers are hot and dry. The plants at Jasper Ridge have developed a variety of strategies for adapting to summer drought conditions. Annual grassland species begin growth in the winter and complete their life cycle with seed production in the late spring. By early summer the annual grasslands are largely senesced.

III. AVIRIS DATA ACQUISITION AND PREPROCESSING

The Jasper Ridge flight line was flown three times in 1989:

1. April 13, 1989 at 12:52 local time - Spring conditions.
2. June 2, 1989 at 13:07 local time - Early summer conditions.
3. September 20, 1989 at 13:48 local time - Early fall conditions.

The April and September data sets were radiometrically corrected at the Jet Propulsion Laboratory, using procedures described by Vane et al. (1987). The radiometric correction includes the following procedures:

1. Correction for vignetting effects (differences in the optical response, depending on the position in the field of view).

2. Subtraction of dark current values (recorded in-flight).

3. Conversion to units of radiance using preflight calibration. This procedure includes a normalization of the response for the individual detectors.

4. Cross track spatial resampling is performed to correct for the detector read out delay. This delay between the read out of successive bands results in a cross track shift of pixels amounting to one pixel between the first and last bands within a spectrometer.

The dark current file for the June data could not be recovered from the flight tape. As a result, the normal radiometric correction could not be applied to the data. The raw June data was simply corrected for the detector read out delay.

IV. CALIBRATION TO GROUND REFLECTANCE

The flight line contains five calibration targets that cover a wide range of reflectance values. The calibration targets are large homogeneous surfaces that are used to develop digital number (DN) to ground reflectance equations in each of the AVIRIS data sets. The brightest target is the flat-lying corrugated metal roof of San Francisco Water Department's Pulgas Balancing Reservoir. The roof is painted a buff tan color and is a reflectance of 35 to 45 %. There are two targets of intermediate brightness, an asphalt parking lot at Canada College and

Humpheries polo field, both having reflectance ranges of 10 to 30 %. Two dark targets are used, Searsville Lake and the black rubber running track at Canada College. The running track reflectance ranges from 1 to 3 %. The lake water is only used for calibration in the infrared, where its reflectance is in the 0.1 to 1.0 % range.

Laboratory reflectance spectra were acquired of samples of the calibration targets (except the lake). Lake water reflectance was measured in 1987 using a field spectrometer suspended over deep water. The digital number values for each calibration target pixel have been paired to the average ground reflectance value determined for the surface in each of the 224 bands. These DN - ground reflectance pairs were plotted and visually examined. Linear regression was used to develop equations to convert DN values into units of ground reflectance. This procedure was repeated for the three dates of imagery, producing three series of gains and offsets for converting AVIRIS DN values to units of ground reflectance. Figures showing the gains and offsets for the three dates of AVIRIS data are provided in Elvidge and Portigal (1990).

V. GRASSLAND SPECTRA

A block of 20 pixels (4 by 5) from the annual grassland was extracted from the three dates of AVIRIS data. The low altitude aerial photograph of Figure 1 was used to locate the same areas for extraction in the three data sets, and to avoid selection of pixels containing isolated trees present in the grassland. The DN values from each block of pixels were averaged and then converted into units of ground reflectance using the equation factors developed through the calibration procedure. The three dates of grassland spectra are plotted in Figure 2.
The three spectra are offset vertically to avoid overlap. The reflectance at 0.8 um is provided for each spectrum.

The April spectrum exhibits chlorophyll and leaf water absorption features, typical of lush green vegetation. Most of the annual plants which were green on April 13 are dry and brown by June 2. Major changes occur in the reflectance of the grassland with the onset of senescence. In the June spectrum there is a loss of chlorophyll absorption, a loss of water absorption at 1.15 um and at longer wavelengths. With the loss of absorption due to leaf water, lignin-cellulose absorptions emerge at 2.09 and 2.27 um. In addition, the slope of the 0.7 to 1.1 um region has increased in the June data. These spectral changes have been documented in laboratory reflectance spectra and are diagnostic for the transition from green to dry-senesced plant materials (Elvidge, 1987 and 1990). The staggered life cycles of the annual plants present in the grassland means that there are still green plants present in June and September. The amount of green vegetation in June and September is less than 5 % cover and consists principally of tarweed and occasional Coyote bushes. The presence of trace quantities of green vegetation during June and September results in the minor chlorophyll red edge present in the spectra at 0.7 um.

VI. CONCLUSION

A series of spectral changes associated with phenological progression have been observed in annual grassland vegetation of the central California coast in three 1989 AVIRIS data sets spanning spring, early summer, and early fall conditions. The grassland spectrum derived from April data exhibits green vegetation spectral features (pronounced chlorophyll and leaf water absorptions, with high reflectance in the 0.8 to 1.2 um region). In the summer and fall data there is a loss of chlorophyll pigment and water absorption. The loss of chlorophyll pigment results in a major decline in the magnitude of the chlorophyll red edge. With the loss of leaf water absorption, there is an emergence of lignin-cellulose absorptions at 2.09 and 2.27 um.

The persistence of the chlorophyll red edge in the June and September data sets is attributed to the presence of trace quantities of green vegetation in the extracted pixels. There are several reasons why the chlorophyll red edge is 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 um. 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.

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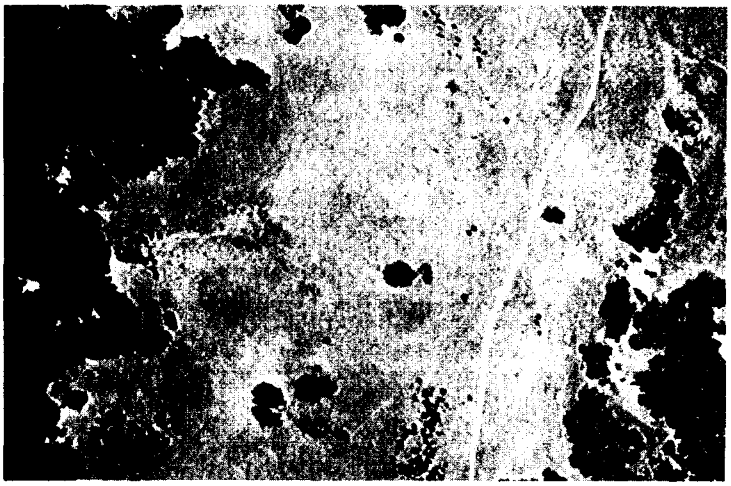

Figure 1. Low altitude aerial photograph of the annual grassland at Jasper Ridge. The grassland is located in the central portion of the slide, with chaparral and oak woodlands present at the edges of the photograph. AVIRIS pixels were extracted from the grassland for the three dates of imagery. The isolated trees in the grassland were avoided during pixel extraction [see slide 17]

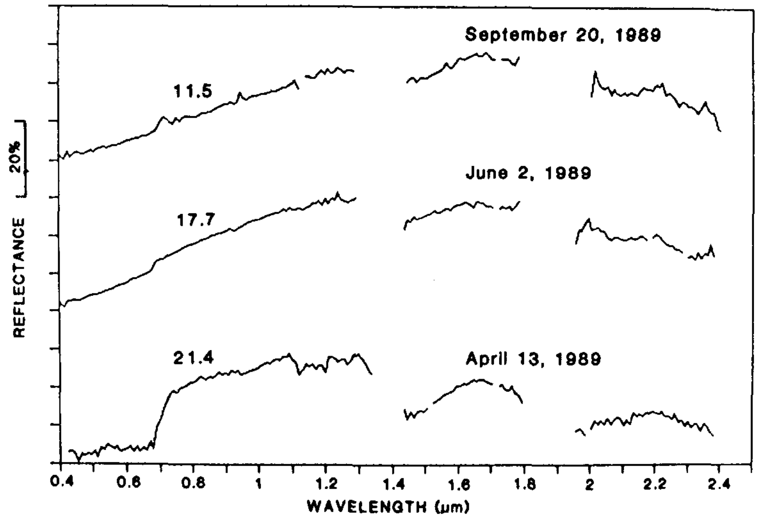

Figure 2. AVIRIS reflectance spectra for the ungrazed grassland from three 1989 AVIRIS data sets. The spectra are derived from the average DNs from a block of pixels from each date which were converted to units of ground reflectance using the calibations presented in Figures 1-3. The spectra have been offset vertically to avoid overlap. The reflectance at 0.8 um is provided for each spectrum