# THE RED EDGE IN ARID REGION VEGETATION: 340–1060 nm SPECTRA

Terrill W. Ray and Bruce C. Murray
Division of Geological and Planetary Sciences
California Institute of Technology
Pasadena, CA 91125

A. Chehbouni and Eni Njoku
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

## 1. Introduction

The remote sensing study of vegetated regions of the world has typically been focused on the use of broad-band vegetation indices such as NDVI. Various modifications of these indices have been developed in attempts to minimize the effect of soil background, e.g., SAVI (Huete, 1988), or to reduce the effect of the atmosphere, e.g., ARVI (Kaufman and Tanré, 1992). Most of these indices depend on the so-called "red edge", the sharp transition between the strong absorption of chlorophyll pigment in visible wavelengths and the strong scattering in the near-infrared from the cellular structure of leaves. These broadband indices tend to become highly inaccurate as the green canopy cover becomes sparse (Huete *et al.*, 1985; Elvidge and Lyon, 1985; Huete and Tucker, 1991).

The advent of high spectral resolution remote sensing instruments such as the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) has allowed the detection of narrow spectral features in vegetation and there are reports of detection of the red edge even for pixels with very low levels of green vegetation cover by Vane *et al.* (1993) and Elvidge *et al.* (1993). High spectral resolution data have led to the use of derivative-based techniques to improve the measurement of low green vegetation levels (Chen *et al.*, 1993) and to characterize algal biomass in coastal areas (Goodin *et al.*, 1993). Spectral mixing approaches similar to those of Smith *et al.* (1990) can be extended into the high spectral resolution domain allowing for the analysis of more endmembers, and, potentially, discrimination between materials with narrow spectral differences.

Vegetation in arid regions tends to be sparse, often with small leaves such as the creosote bush. Many types of arid region vegetation spend much of the year with their leaves in a senescent state, i.e., yellow, with lowered chlorophyll pigmentation. The sparseness of the leaves of many arid region plants has the dual effect of lowering the green leaf area which can be observed and of allowing more of the sub-shrub soil to be visible which further complicates the spectrum of a region covered with arid region vegetation. Elvidge (1990) examined the spectral characteristics of dry plant materials showing significant differences in the region of the red edge and the diagnostic ligno-cellulose absorptions at 2090 nm and 2300 nm. Ray *et al.* (1993) detected absorption at 2100 nm in AVIRIS spectra of an abandoned field known to be covered by a great deal of dead plant litter. In order to better study arid region vegetation using remote sensing data, it is necessary to better characterize the reflectance spectra of *in situ*, living, arid region plants.

## 2. Materials and Method

Field spectra were collected from several characteristic types of desert plants present in the Manix Basin Area of the Mojave Desert, which lies NE of Barstow, California along Interstate-15. The plants were creosote bush (*Larrea divaricata*); bursage (*Artesmia dumosa*); Russian thistle (*Salsola Kali*, commonly "tumbleweed") which was only present as dry balls trapped against creosote or bursage by the wind; and a small grass which is ubiquitous in the area and which has been tentatively identified as fluffgrass (*Erioneuron pulchellum*). Additional spectra were acquired of a few minor plants which were present in the area, as well as a spectrum of an active alfalfa field. These spectra were collected on July 23 and 24, 1993 to correspond to the same time of the year as the AVIRIS data collected on July 24, 1990. A significant potential difference between 1990 and 1993 is the fact that 1990 was a very dry year, while 1993 was a very wet year. The data were collected using a Personal Spectrometer 2 (PS-2) which uses a silicon detector to measure a spectral range from 335 to 1064 nm in 512 channels which are approximately 1.4 nm wide.

Spectra of shrub-type plants were collected in two different modes. The first is the plant spectra that include both canopy and underlying soil contributions. For the second mode a dark background was placed underneath the shrub so as to cover the sub-shrub soil. This dark background consisted of railroad board painted with ultra-flat black Krylon spray paint which has a very low reflectivity from the ultraviolet through 20 $\mu$m.[1] Five spectra were collected at each target. Photographs were also taken of each target to allow estimates of how much soil or dark target were visible in each case. Each target was located using chain and a Brunton compass.

## 3. Preliminary Results

Figure 1 shows the spectra of the alfalfa field and of the most common native plants in the area. In each case, the field of view of the spectrometer is effectively filled by the plant(s). In figure 1a the classic green vegetation reflectance spectrum is readily apparent in the case of the irrigated alfalfa field. The chlorophyll "bump" between .5 and .6 $\mu$m is clear and distinct, and there is a sharp red edge at the transition between red and near-infrared leading to a high reflectance plateau. The NDVI value from this spectrum is 0.8686.

Creosote bush is shown in figure 1b. This spectrum is the average spectrum based on the spectra recorded for four different individuals with the soil as the background. The chlorophyll "bump" is not nearly as distinct, although it is still present in a somewhat suppressed form. The red edge is still a fairly sharp step to a plateau of moderate near-infrared reflectance, but the step is significantly smaller than that for the alfalfa field. The NDVI which results in this case is 0.7264. When the creosote is recorded against the dark background, the chlorophyll "bump" is more pronounced and a slightly higher NDVI of 0.7314 results.

Figure 1c shows the average spectrum of four bursage shrubs. In this case, the chlorophyll "bump" is very indistinct and forms part of a plateau of slightly elevated reflectance which stretches from .55–.65 $\mu$m. The red edge transition is much smaller than in the case of either creosote bush or alfalfa. Additionally, the reflectance in the .4–.5 $\mu$m region is higher than seen in figures 1a and 1b. The NDVI computed from this spectrum is 0.4253.

A spectrum of a senescent grass which is ubiquitous in this area is shown in figure 1d. The spectrum is an average of two different sites. None of the fea-

[1] Westphal, personal comm., 1993.

tures typically associated with vegetation are apparent in this spectrum; there is no chlorophyll "bump" nor is there a perceptible red edge. The NDVI calculated from this spectrum is 0.1316, which is a value which could correspond to completely bare soil. This means that an area completely covered with this grass at this time of year would appear nearly barren. This grass has been tentatively identified as fluff grass, which is a perennial.

The examples shown in figure 1 clearly demonstrate that NDVI is not a satisfactory method for observing and quantifying vegetative cover in arid regions. The examples in this paper are based on cases where the instrument field of view is completely filled by the particular plant in question, and this problem will be greatly magnified when the vegetation cover is sparse. Additionally, these spectra are atmospherically corrected while measurements of NDVI from spaceborne systems often depend on data without an atmospheric correction, which tends to decrease the red–near-infrared contrast and further suppress NDVI.

## 4. Future Work

The spectra collected in this experiment will be used in analysis of AVIRIS and Landsat data which cover the Manix Basin area and other areas of the southwestern U.S. Repeat spectra of each target will be collected in October 1993, January 1994, April 1994, and July 1994 to characterize seasonal changes in spectral characteristics. In the case of annual plants, such as Russian Thistle, a representative plant from the immediate area of the original target will be chosen. The repeat observations may include measurements with a PIMA spectrometer which covers the 1300 to 2500 nm range. This work may lead to the devlopment of a better index for monitoring vegetation dynamics in arid regions.

## 5. Acknowledgements

The authors would like to thank Curtiss Davis at JPL for the use of the PS2 spectrometer. Lisa Gaskell and Becky Zaske, undergraduates in Caltech's Division of Geological and Planetary Sciences, were instrumental in the collection of the field data.

## 6. References

Chen, Z., C. D. Elvidge, and W. T. Jansen, Description of derivative-based high spectral-resolution (AVIRIS) green vegetation index, unpublished manuscript, 1993.

Elvidge, C. D., Visible and near infrared reflectance characteristics of dry plant materials, *Int. J. Remote Sens., 11*:1775–1795, 1990.

Elvidge, C. D., Z. Chen, and D. P. Groeneveld, Detection of trace quantities of green vegetation in 1990 AVIRIS data, Remote Sens. Environ., 44:271–279, 1993.

Elvidge, C. D. and R. J. P. Lyon, Influence of rock-soil spectral variation on the assessment of green biomass, *Remote Sens. Environ., 17*:265–279, 1985.

Goodin, D. G., L. Han, R. N. Fraser, D. C. Rundquist, W. A. Stebbins, and J. F. Shalles, Analysis of suspended solids in water using remotely sensed high resolution derivative spectra, *Photo. Eng. Remote Sens., 49*:505–510, 1993.

Huete, A. R., A soil-adjusted vegetation index (SAVI), *Remote Sens. Environ., 25*:295–309, 1988.

Huete, A. R. and C. J. Tucker, Investigation of soil influences in AVHRR red and near-infrared vegetation index imagery, *Int. J. Remote Sens., 12*:1223–1242, 1991.

Huete, A. R., R.D. Jackson, and D. F. Post, Spectral response of a plant canopy with different soil backgrounds, *Remote Sens. Environ., 17*:37–53, 1985.

Kaufman, Y. J. and D. Tanré, Atmospherically resistant vegetation index (ARVI) for EOS-MODIS, *IEEE Trans. Geosci. Remote Seits. 30*:261–270, 1992.

Ray, T. W., T. G. Farr, and J. J. van Zyl, Study of land degradation with polarimetric SAR and visible/near-infrared spectroscopy, *Proceedings of Topical Symposium on Combined Optical-Microwave Earth and Atmosphere Sensing*, 228–231, 1993.

Smith, M. O., S. L. Ustin, J. B. Adams, and A. R. Gillespie, Vegetation in deserts: I. A regional measure of abundance from multispectral images, *Remote Sens. Environ.*, *31*:1–26.

Vane, G., R. O. Green, T. G. Chrien, H. T. Enmark, E. G. Hansen, and W. M. Porter, The airborne visible/infrared imaging spectrometer (AVIRIS), *Remote Sens. Environ.*, *44*:127–143, 1993.

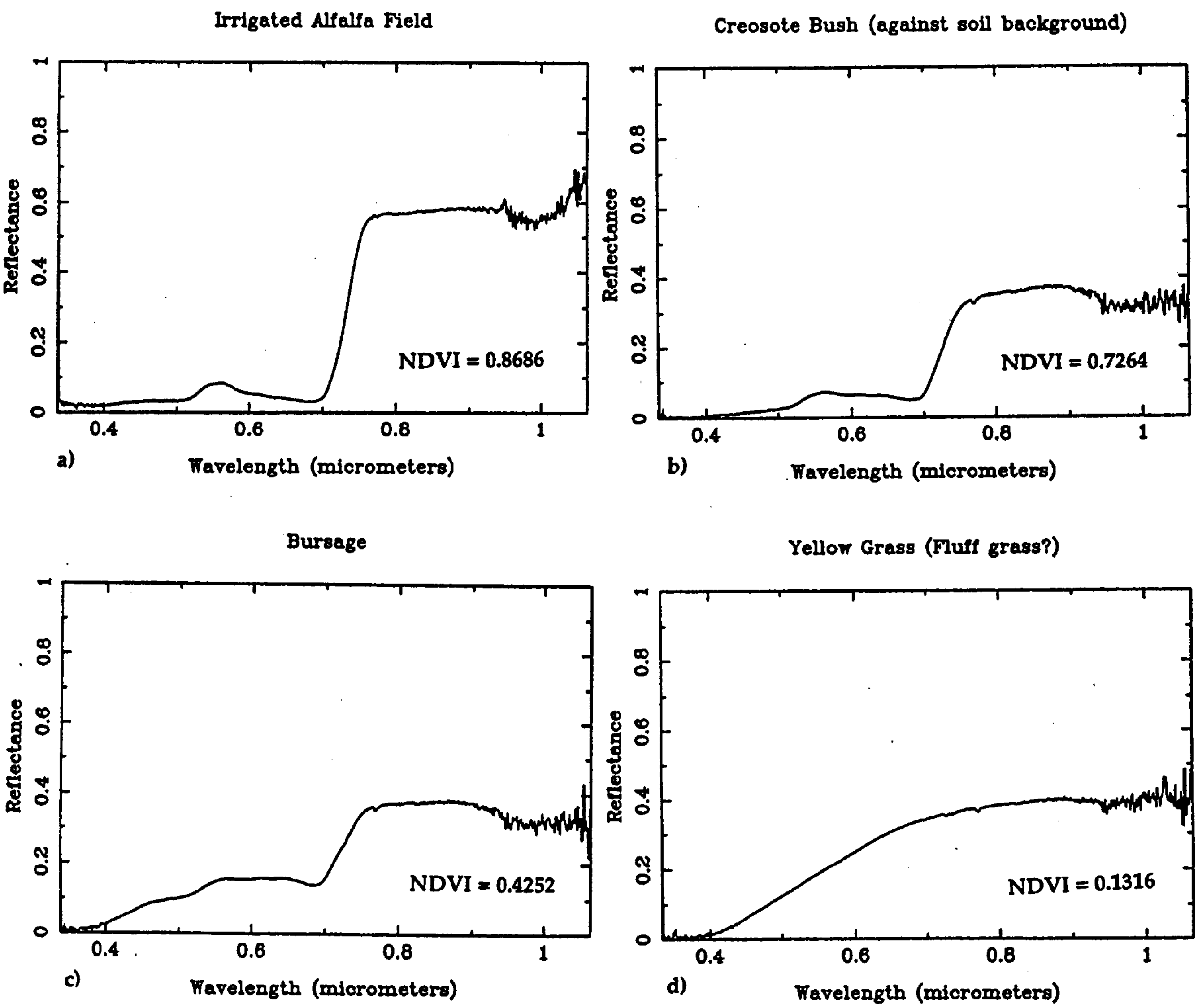


**Figure 1:** Spectra for some common Mojave Desert plant types and for an active irrigated alfalfa field in the Manix Basin area. In each case, the instrument field of view is completely filled by the vegetation being measured (100% vegetation cover). Compare the shapes of the spectra in the visible region and the nature of the red edge. NDVI values for each spectrum are listed to illustrate the poor performance of NDVI when looking at arid region vegetation. **a)** Irrigated alfalfa field. **b)** Creosote Bush. **c)** Bursage. **d)** An extremely common grass which is yellow most of the year; tentatively identified as fluff grass.