MAPPING CHAPARRAL IN THE SANTA MONICA MOUNTAINS USING MULTIPLE ENDMEMBER SPECTRAL MIXTURE MODELS

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1. INTRODUCTION

California chaparral is one of the most important natural vegetation communities in Southern California, representing a significant source of species diversity and, through a high susceptibility to fire, playing a major role in ecosystem dynamics. Due to steep topographic gradients, harsh edaphic conditions and variable fire. histories, chaparral typically forms a complex mosaic of different species dominants and age classes, each with unique successional responses to fire. and canopy characteristics (e.g. moisture content, biomass, fuel lea(i) that modify fire susceptibility. The high human cost of fire and intimate mixing along the urban interface combine to modify the natural fire regime as well as provide additional impetus for a better understanding of how to predict fire and its management. Management problems have been further magnified by nearly seventy years of fire suppression and drought related die-back over the last few years resulting in a large accumulation of highly combustible fuels (Radtke et al., 1 982; Yool et al., 1985). Chaparral communities in the Santa Monica Mountains exemplify many of the management challenges associated with fire and biodiversity.

A study was initiated in the Santa Monica Mountains 10 investigate the use of the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) for providing improved maps of chaparral coupled with direct estimates of canopy attributes (e.g. biomass, leaf area, fuel load). The Santa Monica Mountains are an east-west trending range located approximately 75 kilometers north of Los Angeles extending westward into Ventura County. Within the Santa Monica Mountains a diverse number of ecosystems are located, including four distinct types of chaparral, wetlands, riparian habitats, woodlands, and coastal sage scrub. In this study we focus on mapping three types of chaparral, oak woodlands and grasslands. Chaparral mapped included coastal sage scrub, chamise chaparral and mixed chaparral that consisted predominantly of two species of Ceanothus.

2. METHODS and STUDY SITE

Analysis focused on AVIRIS data collected on October 19, 1994. Two east-west flight lines were collected, consisting of a total of 12 scenes. Results will only be presented for scene 5, centered over Point Dume, California (Fig. 1). Maps of equivalent liquid water thickness, precipitable water vapor and apparent reflectance were generated using an algorithm coupled with the Modtran3 radiative transfer code (Green et al., 1993). Once converted to apparent reflectance, AVIRIS data were modeled as spectral mixtures of field and laboratory measured spectra of soil, non-photosynthetic vegetation (NPV), green leaves and shade (Adams et al., 1993; Roberts et al., 1993). Spectral mixture analysis (SMA) was performed using a complex modeling approach, in which the number of endmembers and types of endmembers were varied on a per-pixel basis (Roberts et al., 1992). This approach has advantages over the simple mixture model because it offers the potential for greater separation of communities through ecosystem unique endmember selection while minimizing fraction errors that typically result from endmember ambiguity or interpixel differences in spectral dimensionality (Sabol et al., 1 W').

Reference endmembers were selected from a library of field and laboratory spectra collected during two field campaigns, in June and September 1995 (Ustin et al., ibis volume). Endmembers were selected using techniques described by Smith et al., (1990a) and Adams et al., (1993). These techniques were used to develop suites of candidate endmembers for green vegetation and NPV for each major community in the study area. A single soil and photometric shade spectrum were selected for simplicity, although community level variability in shade, spectra can be significant due to multiple scattering of NIR light (Roberts et al., 1993). Suites of candidate spectra were developed hierarchichally, starting with two-endmember models, followed by three endmember models etc. Training areas for each major vegetation type were extracted from the reflectance images and used to guide the development of a candidate library. The final library consisted of 3 leaf spectra, 2 NPV spectra and one each of soil and shade. Candidate leaf spectra for coastal sage scrub, chamise chaparral and mixed chaparral are shown labeled as S24PNL, adfa and ceme, respectively (Fig. 2). A fourth spectrum consisting of NPV is included on the figure labeled Erci stem (Eriogonum cinareum). The best fit for a leaf in coastal sage scrub was actually an NPV spectrum, reflecting the drought deciduous behavior of many dominants in this community.

Once a candidate library was developed, the library was used as an input into a series of mixture models starting with all reasonable combinations of two-endmembers models (leaf-shade, soil-slink, NPV-shade) followed by all possible three endmember models (leaf-NPV-sll;\ (le.) and four endmember models. A total of 14 models were run. Following mixture modeling, a program was developed to select the optimal model for each pixel based on RMS error and spectral fractions. Starting with models with the lowest dimensionality (two-endmember models), each pixel was evaluate..l based on an RMS threshold of < 2.5% and the constraint that fractions ranged between -1 % and 1 00%. Once a pixel met these criteria, it was assigned a numeric value equal to the model and removed from the pool. This approach was continued, progressing upwards from models of low-dimensionality to high dimensionality until all models had been evaluated. This resulted in a map consisting of 14 classes, in which class was determined by the number of endmembers in the model and (he, types that were used. Class maps and fraction images were combined to produce images showing the spectral fractions associated with each green leaf endmember. Fraction maps were then combined with equivalent liquid water maps to produce a final classified image using techniques described by Adams at al., (1995), modified to include liquid water.

3. RESULTS

Using a multiple endmember mixing model over 9.5% of the image could be modeled as some combination of 2 to 4 endmembers at an RMS < 2.5% and with positive fractions. The only unmodeled areas consisted of the city of Malibu and Zuma beach. In chaparral the dimensionality of individual spectra was remarkably low, with 2-endmember models accounting for 6S.9 percent and 3 endmember models accounting for 9?.3 percent Of the total pixels (Table]). Although preliminary, based on the field sites and limited field photographs the model appears to have successfully separated chamise chaparral from mixed chaparral and mapped the extent of coastal sage scrub. Near-term objectives are to evaluate map accuracy and refine models based on field observations and aerial photographs. Spring AVIRIS data acquired in 1995 will also be incorporated to study seasonal effects and evaluate any phenological improvements for mapping.

Table 1. Showing the number Of pixels modeled using ?, 3 and 4 endmember models. 13,324 of a total 314,368 image pixels were left unmodeled using a combination of the ?, 3, and 4 endmember models. Note, ~10% of the image was ocean, which was selected by the first 2-endmember model, Ceme.

Model Leaf Endmember	2-endmember	3-endmember (includes NPV)	4-endmember (includes soil)	Totals
Ceme	136677	68186	7443	212306
Adfa	9729	12s?6	2373	24628
Oak (l'l'NI',)	192	699	106-/	1958
Zuma (S24PNL)	55286	1497	3	56786
Senesced (bass	2334	X	X	2334
Soil	3032	X	X	3032
Total Unmodeled	107118	24210	**13324**	X
Total Modeled	?072so"	82908	10886	301(144

4. REFERENCES

Adams, J. B., Smith, M, C). and Gillespie, A. R., 1993, Imaging spectroscopy: Interpretation based on spectral mixture analysis, In Pieters C. M., anti Englert, P., eds. Remote Geochemical Analysis: Elemental and Mineralogical Composition 7: 145-1 66, Cambridge Univ. Press., NY.

Adams, J.B., Sabol, 1)., Kapos, V., Almeida Filho, R., Roberts, D. A., Smith, M. O., Gillespie, A. R., 1995, Classification of Multispectral Images Based on Fractions of Endmembers: Application to Land-Cover Change in the Brazilian Amazon, *Rem. Sens. Environ, 52: 137-154.*

Green, R.O., Conel, J.E. anti Roberts, D. A., 1993, Estimation of Aerosol Optical Depth and Additional Atmospheric Parameters for the Calculation of Apparent Surface Reflectance from Radiance Measured by the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS), *Summaries of the 4th Annual JPL Airborne* Gco.wiener Workshop, *Oct* 2.5-29, Vol. 1. AVIRIS Workshop, Washington D. C., 73-76.

Radtke, K.W. 11., Arndt, A.M., and Wakimoto, R.H., 1982, Fire history of the Santa Monica Mountains, in Proc. Symp. Dynamics and Management of Mediterranean-type Ecosystems. San Diego, Ca, USFS General Technical Report PSW-58: 438-443.

Roberts, D. A., Smith, M.()., Sabol, D.E., Adams, J.B. and Ustin, S., 1992, Mapping the Spectral Variability in Photosynthetic and Non-Photosynthetic Vegetation, Soils and Shade using AVIRIS, *Summaries 3rd Annual JPL Airborne Geoscience Workshop: Vol. 1, A VIRIS*, Pasadena, CA. Jane 1 and 2, 1992, pp. 38-40.

Roberts, D. A., Adams, J.B., and Smith, M.O., 1993, Discriminating Green Vegetation, Non-Photosynthetic Vegetation and Soils in AVIRIS Data, *Rem. Sens. Environ.*, 44: ?./3 ?55-270.

Sabol, D.E., Adams, J.B., and Smith, M.O., 1992, Quantitative sub-pixel spectral detection of targets in multispectral images, *J. Geophys. Res.* 97:2659-2672.

Smith, M.O., Ustin, S.1 ,., Adams, J. B., and Gillespie, A.R., 1990, Vegetation in deserts: I A regional measure of abundance from multispectral images, *Remote Sens. En viron.*, 31: 1 -?.6.

Ustin, S.1 . . . Scheer, G., Castaneda, C.M., Jacquemoud, S., Roberts, D., and Green, R., *1996,* Estimating canopy watt.r content of chaparral shrubs using optical methods, this volume.

Yool, S, R., Eckhardt, D. W., and Cost.ntilm, M. J., 1985, Describing the brushfire Its?.ald in southern California. *Anal. Assoc. Am. Geograph.* 75:431 -44?.

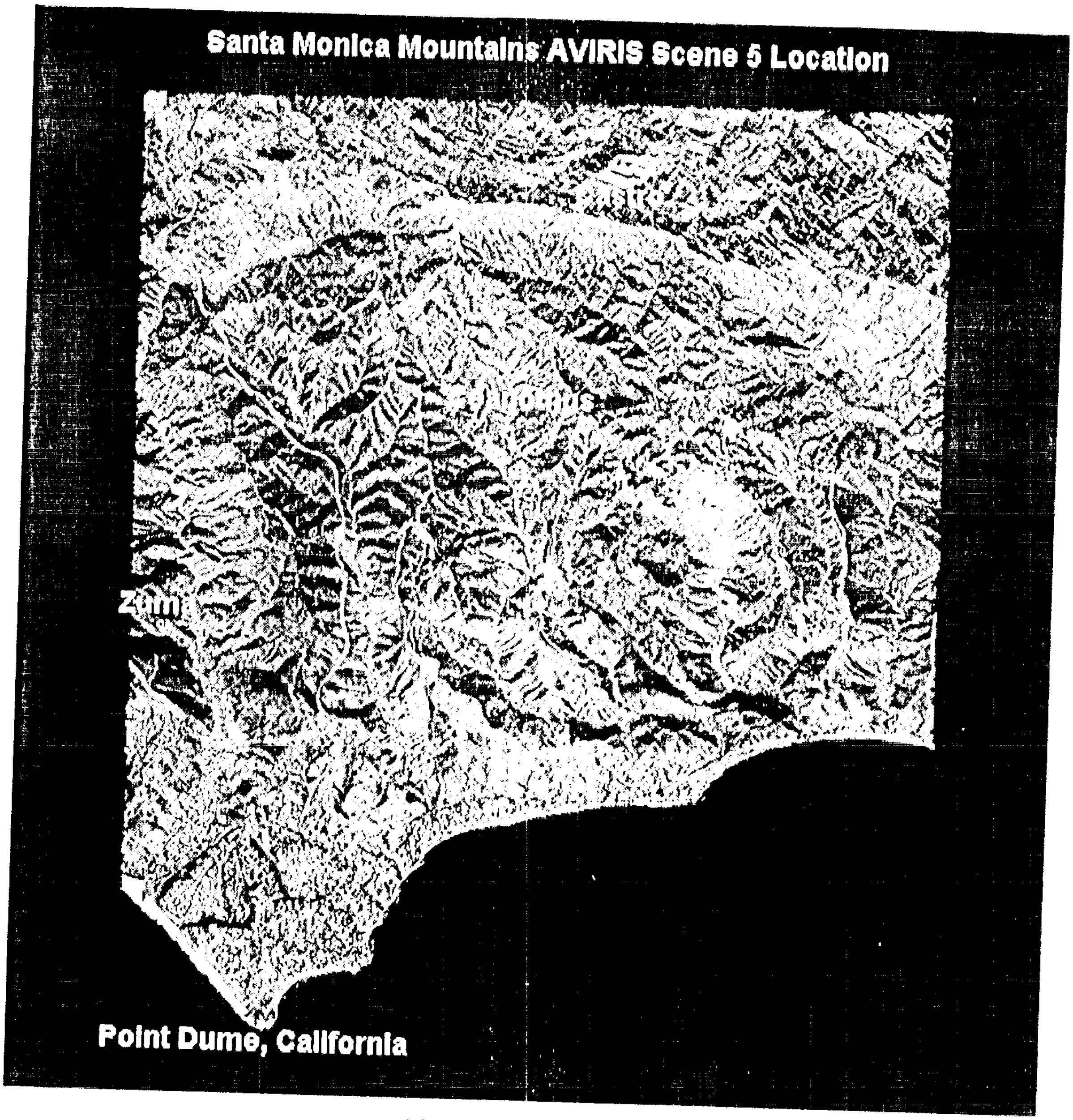

Figure1. Showing locations of the Chamise chaparral (Castro) and Coastal sage scrub (Zuma) field sites Ceanothus marks a third site identified to be almost pure Ceanothus from fieldphotographs.

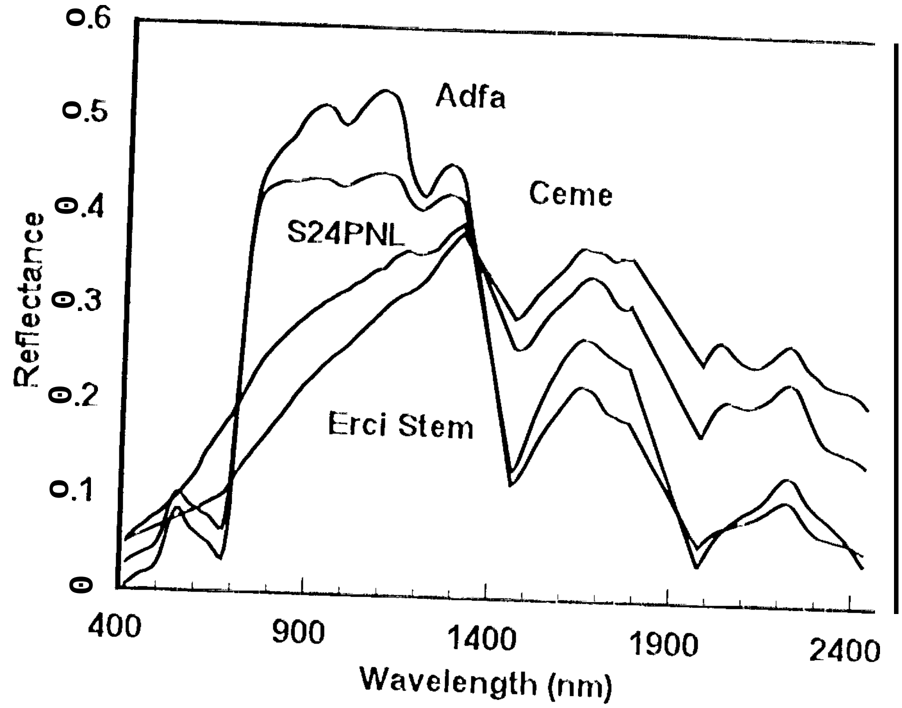

Figure 2. Showing reference endmembers selected for Castro (Adfa = Adenostoma fasciculatum), Ceanothus (Ceme = Ceanothus megacarpus), Zuma (S24PNL = an NPV) and NPV (Erci Stem = Eriogonum cinareum stem).