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USING ENDMEMBERS IN AVIRIS IMAGES TO ESTIMATE CHANGES IN VEGETATIVE BIOMASS

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Field techniques for estimating vegetative biomass are labor intensive, and rarely are used to monitor changes in biomass over time. Remote-sensing offers an attractive alternative to field measurements; however, because there is no simple correspondence between encoded radiance in multispectral images and biomass, it is not possible to measure vegetative biomass directly from AVIRIS images. We are investigating ways to estimate vegetative biomass by identifying community types and then applying biomass scalars derived from field measurements.

Field measurements of community-scale vegetative biomass can be made, at least for local areas, but it is not always possible to identify vegetation communities unambiguously using remote measurements and conventional image-processing techniques. Furthermore, even when communities are well characterized in a single image, it typically is difficult to assess the extent and nature of changes in a time series of images, owing to uncertainties introduced by variations in illumination geometry, atmospheric attenuation, and instrumental responses.

Our objective is to develop an improved method based on spectral mixture analysis to characterize and identify vegetative communities, that can be applied to multi-temporal AVIRIS and other types of images. In previous studies we analyzed multi-temporal data sets (AVIRIS and TM) of Owens Valley, CA (Smith et al., 1990) and (TM) of Manaus, Brazil (Adams et al., 1990, and in prep), and defined vegetation communities in terms of fractions of reference (laboratory and field) endmember spectra. An advantage of converting an image to fractions of reference endmembers is that, although fractions in a given pixel may vary from image to image in a time series, the endmembers themselves typically are constant, thus providing a consistent frame of reference.

In the Owens Valley we found that several shrub, riparian and conifer communities could be characterized by the fractions of two types of green vegetation and of shade, in addition to two types of soil. On the shrub-covered bajada the fraction of vegetation (GVF) and the fraction of shade correlated linearly with vegetation cover and with biomass, as determined on the ground. However, the fractions of these endmembers also varied predictably with seasonal changes, emphasizing that any estimates of biomass from AVIRIS or TM images must take into account the season of measurement.

In TM images of Manaus we found that several vegetation communities could be identified by the fractions of the endmembers green vegetation, non-photosynthetic vegetation (NPV), shade and soil. For example, primary forest has a high proportion of NPV (from branches and stems exposed in the canopy) and shade (from shade and shadow associated with canopy roughness). Using fractions of reference endmembers, we were able to consistently identify vegetation communities and changes in communities in TM images over time. The importance of NPV endmembers was further demonstrated in an analysis of AVIRIS images of Jasper Ridge, CA (Roberts et al.,1992).

To further test the identification of a range of vegetation communities using fractions of reference endmembers (Figure 1), we analyzed two sets of multi-temporal

AVIRIS images, one of Jasper Ridge, CA (see Roberts et al., this volume) and Shasta, CA (see Ustin et al., this volume). Six images of the same area near Shasta were obtained on one day at 45 minute intervals about solar noon, providing an opportunity to test how endmember fractions behaved with changing illumination geometry.

In addition to studying multi-temporal AVIRIS data sets we have developed a way to expand the number of endmembers applied to AVIRIS images. In previous analyses we have characterized all of a scene by a few (usually 3-5) endmembers and the residuals for each pixel (e.g. Gillespie et al., 1990). We have now applied a new technique to the above AVIRIS scenes that produces different sets of endmembers for each pixel, in addition to the residuals. This approach expands the potential number of endmembers, while at the same time specifying no more than the number of endmembers needed to fit each pixel. (Sabol et al, 1992 have shown that fitting image data with endmembers that are not present introduces noise and lowers detectability.) The multiple-endmember approach has significantly improved our ability to characterize vegetation communities in AVIRIS and other images. Different communities are fit by different endmembers and by different numbers of endmembers. For example, a pine-forest community near Shasta is fit by spectral mixtures of green vegetation, woody material and shade. In the same scene, shrub and grass communities are fit by the spectra of different green vegetation, NPV and shade, and by characteristic fractions of these endmembers.

Although the fraction of green vegetation in images of the Owens Valley shrubland correlated well with cover and biomass, we emphasize that in general, single parameters such as the fraction of green vegetation, or proxies for the green vegetation fraction (e.g., the normalized-difference vegetation index, NDVI), are not always reliable indicators of biomass. For example, a green pasture and a closed-canopy forest both have high fractions of green foliage but differ substantially in biomass. However, our recent results using reference endmembers indicate that many types of vegetation communities can be identified in sets of AVIRIS images, independent of illumination geometry, and atmospheric and instrumental effects. Measurements of biomass in the field can be linked to vegetation communities that are well characterized by fractions of different types of green foliage and NPV. In addition, the shade fraction is influenced by plant size, spacing and architecture, and can assist in defining the community type.

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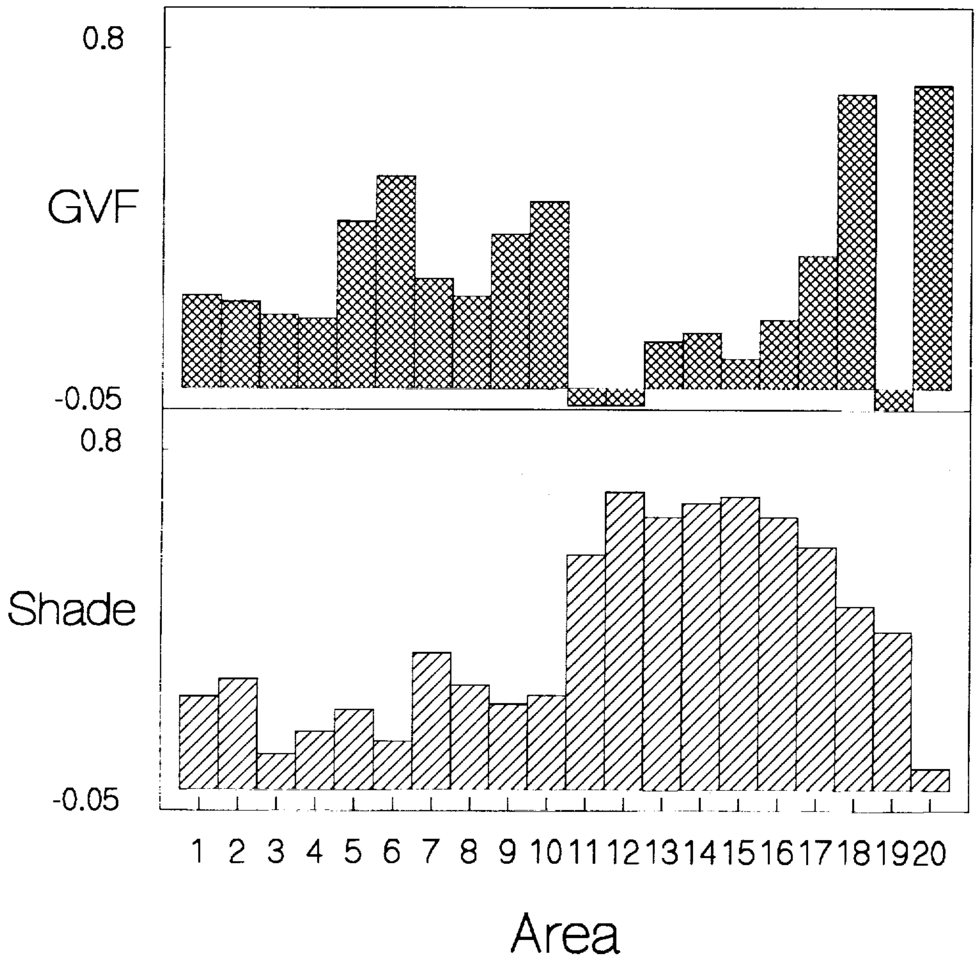

Figure 1.
The G_{vf} and shade fraction for 20 areas of diverse vegetation communities of AVIRIS images of Jasper Ridge and Shasta, CA. The areas are 1) 1st clear cut area 2) 2nd clear cut area 3) 1st recent clear cut area 4) 2nd recent clear cut area 5) second growth ponderosa pine plantation 6) 1st mature ponderosa pine forest 7) 2nd mature ponderosa pine forest 8) 2nd young second growth ponderosa pine stand 9) 1st young second growth stand 10) meadow 11) ungrazed non serpentine drygrass, 12) serpentine grassland, 13) serpentine chaparral, 14) nonserpentine chaparral, 15) nonserpentine chaparral with dieback, 16) blue oak ,17) evergreen oak, 18) forest wetland, 19) grassland at Webb ranch, and 20) golf course. The G_{vf} does not provide a reasonable estimate of biomass over all communities. The vegetation fractions do not correspond to a ranking that coincides with the biomass. The meadow, for example, has a higher vegetation fraction than any of the forested areas but has a lower biomass. Even when shade is normalized out of the remainder of fractions the forest contains other nonphotosynthetic endmembers not part of the G_{vf}.