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DISCRIMINATION AMONG SEMI-ARID LANDSCAPE ENDMEMBERS USING THE SPECTRAL ANGLE MAPPER (SAM) ALGORITHM

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1. INTRODUCTION

Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data were acquired during three consecutive seasons of the year (26 September 1989, 22 March 1990, and 7 August 1990) over an area of the High Plains east of Greeley, Colorado. This region contains extensive eolian deposits in the form of stabilized dune complexes (small scale parabolic dunes superimposed on large scale longitudinal and parabolic dunes). Due to the dunes' large scale (2-10 km) and low relief (1-5 m), the scaling relationships that contribute to the evolution of this landscape are nearly impossible to understand without the use of remote sensing. Additionally, climate models indicate that the High Plains could be one of the first areas to experience changes in climate caused by either global warming or cooling (Hansen *et al.*, 1988). During the past 10,000 years there were at least three periods of extensive sand activity, followed by periods of landscape stability, as shown in the stratigraphic record of this area (Forman, *et al.*, 1992). Therefore, if the past is an indication to the future, the monitoring of this landscape and its sensitive ecosystem is important for early detection of regional and global climate change.

2. STUDY AREA CHARACTERISTICS

The dune complexes found along the South Platte River are currently stabilized by a thin cover of shortgrass prairie vegetation species. These include blue grama, sand bluestem, and sandreed bunchgrasses, along with other graminoids and perennial forbs (yucca, sage, cacti). Because there is very little, if any, topsoil over the sands, the land is used primarily for grazing. There are sites along the terraces and floodplain of the South Platte River where the soils are thicker and where either dryland or irrigated farming is conducted. Therefore, a wide range of percent vegetation cover occurs in each image (from 0% in overgrazed or blowout areas to 100% in irrigated fields). In order to fully describe each scene, image endmembers in three categories (vegetation, soil, and water) were chosen. Up to ten total image endmembers were used (see figure 1).

3. SPECTRAL ANGLE MAPPER ALGORITHM

AVIRIS radiance values were converted to reflectance using the scaled surface reflectance method of Gao (Gao, *et al.*, 1991, 1992). This method derives atmospheric water vapor radiance values for each pixel of a scene using the water vapor features found at 0.94 and 1.14 μm. The atmospheric water vapor values are then subtracted from the radiance value of each pixel, resulting in an atmospherically corrected image across the entire 0.4-2.5 μm region.

Atmospherically corrected images were then imported into the Spectral Image Processing System (SIPS) developed at CSES (Kruse, *et al.*, 1992). This package allows one to extract spectra from individual or groups of pixels and compute statistics for regions of similar composition (i.e., the image endmembers). The mean spectra of up to ten endmembers can then be processed using the Spectral Angle Mapper (SAM) algorithm.

This technique, developed by J.W. Boardman, determines the spectral similarity between given reference spectra, *r*, (i.e., the image endmember in this case) and the spectra found at each pixel, *t* (Kruse, *et al.*, 1992). The result of the comparison is reported as the angular difference (in radians) between the two spectra according to the equation:

$$\cos^{-1}\left(\frac{\vec{t}\cdot\vec{r}}{\|\vec{t}\|\cdot\|\vec{r}\|}\right)$$

which can also be written as,

$$\cos^{-1}\left(\frac{\sum_{i=1}^{nb} t_i r_i}{\sqrt{\sum_{i=1}^{nb} t_i^2}\sqrt{\sum_{i=1}^{nb} r_i^2}}\right)$$

Here *nb* is the number of bands in the image. Each pair of spectra is treated as a vector in *nb*-space, allowing the similarity of the spectra to be determined without regard to their relative brightness values. The result of the SAM calculation is an image for each reference spectrum, with high values (displayed in brighter values) corresponding to a better match between reference and test spectra.

4. RESULTS

When the ten image endmembers shown in figure 1 were processed via the SAM algorithm, excellent discrimination between the different endmembers was found. Figures 2 and 3 show the SAM results for image endmembers located on the sparsely vegetated dune limbs and the more densely vegetated dune depressions, respectively. We believe these results show the sensitivity of the method since the difference in percent vegetation cover between the two areas indicated above is no greater than 20%. Traditional Normalized Difference Vegetation Index (NDVI) methods show no such discrimination, and only minor discrimination occurs using linear unmixing techniques. Because vegetation cover density is critical to the stability of the landscape, and any climate change would cause this to also change, the SAM algorithm may provide the sensitivity needed to discriminate between minor changes of vegetation cover that could lead to major changes in the landscape, and thus, allow early detection of global climate change.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Forman, S.L., A.F.H. Goetz, and R.H. Yuhas, 1991. Large-scale stabilized dunes on the High Plains of Colorado: Understanding the landscape response to Holocene climates with the aid of images from space: *Geology* **20**, pp. 145-148.

Gao, B.-C., A.F.H. Goetz, and J.A. Zamudio, 1991. Retrievals of surface reflectances from AVIRIS data: in Proceedings, IGARSS '91, University of Maryland, College Park, MD, The Institute of Electrical and Electronics Engineers, Inc., New York, **2**, pp. 669-672.

Gao, B.-C., K.H. Heidebrecht, and A.F.H. Goetz. Derivation of scaled surface reflectances from AVIRIS data: *Remote Sensing of Environment* (submitted), February 1992.

Hansen, J., I. Fung, A. Lacis, D.S. Rind, R. Ruedy, and G. Russell, 1989. Global climate changes as forecast by Goddard Institute for Space Studies three-dimensional model: *Journal of Geophysical Research* **93**, pp. 9341-9364.

Kruse, F.A., A.B. Lefkoff, J.B. Boardman, K.B. Heidebrecht, A.T. Shapiro, P.J. Barloon, and A.F.H. Goetz, 1992. The Spectral Image Processing System (SIPS)--Interactive visualization and analysis of imaging spectrometer data: *Remote Sensing of Environment* (in press, for release July 1992).

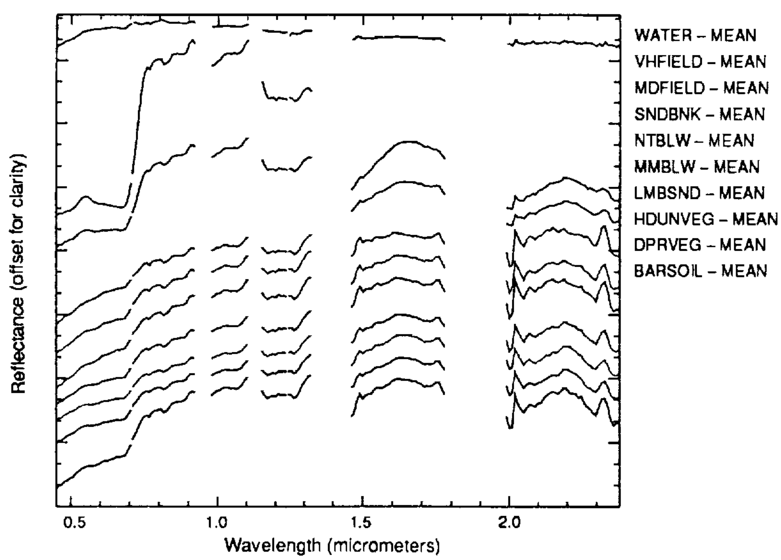

Figure 1. Spectra of the ten image endmembers used as input to SAM.

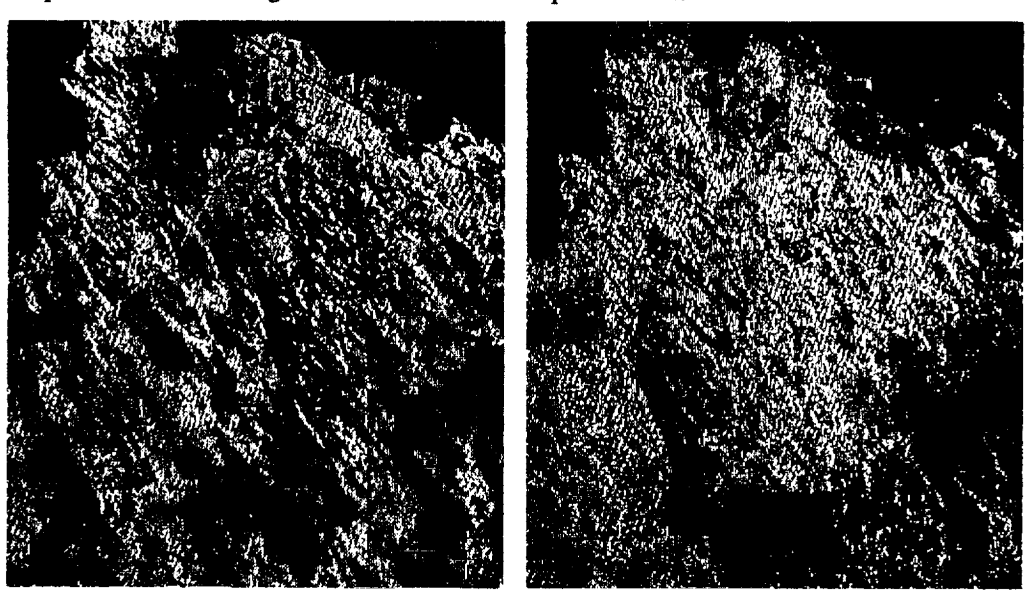

Fig. 2 and 3. SAM images for dune limb (left) and dune depression endmembers (right).