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AIS SPECTRA FOR STRESSED AND UNSTRESSED PLANT COMMUNITIES IN THE CAROLINA SLATE BELT

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ABSTRACT

Airborne imaging spectrometer (AIS) data were collected over a number of derelict heavy metal mine sites in the Carolina slate belt of North Carolina. A 32 channel (1156 - 1456 nm) data set was acquired in October, 1983 at the time of peak fall foliage display, and a 128 channel (1220 - 2420) data set was acquired near the end of the spring leaf flush in May, 1984. Spectral curves were extracted from the AIS data for differing ground cover types (e.g., pine forests, mixed deciduous forests, mine sites, and pastures). Variation in the width of an absorption feature located at approximately 1190 nm has been related to differences in forest type. Small differences in the location and shape of features in the near infrared plateau (1156 - 1300 nm) and the region 2000 - 2420 nm have yet to be evaluated. Because these variations were subtle, and because atmospheric effects were apparent in the data, high priority must be assigned to devising a means of removing atmospheric effects from AIS spectra.

INTRODUCTION

Extensive ecological studies of vegetation on and near derelict heavy metal mine sites in the Carolina slate belt of the North Carolina Piedmont (Wickland, 1983) prompted a remote sensing study of the area (Wickland, 1984). The main objective of the remote sensing study was to attempt to identify spectral charactistics of vegetation related to the type of stress the vegetation was experiencing. Airborne imaging spectrometer (AIS) data were acquired as part of this study because high spectral resolution data seemed to have great potential for uniquely identifying stress factors. Two AIS data sets were acquired. In October, 1983, at the time of peak fall foliage display, a 32 channel (1156 - 1456 nm) data set was acquired for 6 flightlines. In May, 1984, near the end of the spring leaf flush, a 128 channel data set (1220 - 2420 nm) was acquired for 4 flightlines.

METHODS OF DATA ANALYSIS

For the 32 channel fall data set, raw, logged data (i.e., neither atmospheric nor solar irradiance corrections were applied) were subjected to the Walsh-Hadamard transformation and Principal Components analysis. Color composites of the first three components from both transformations provided essentially the same information, but the color contrast in the principal components image was somewhat more pleasing. Spectra were extracted from the raw data using the program ISCAN. Vertical striping was evident in the fall imagery, and the imagery lacked crispness due to hazy skies at the the time of acquisition.

For the 128 channel spring data set, the raw, logged data were subjected to a correction for the solar spectral irradiance. Again, atmospheric effects were not removed. Ground reflectance data were acquired at the time of the overflight for the purpose of flatfield correction, but the flightline involved could not be logged properly. Spectra were extracted from other flightline data sets using the program SPAM. There was little haze at the time of the spring overflights, and the AIS imagery was much crisper. Horizontal data loss bands due to interference by the Nikon camera were visible in the images.

RESULTS AND DISCUSSION

Fall Imagery

All ground cover types discernible in color infrared photography and Thematic Mapper Simulator imagery were clearly distinguishable in the fall AIS imagery. Farm ponds in the image for a flightline in the Virgilina area did not have the low, flat spectra expected of water in the near infrared. Although algae or sediments in the ponds could have been responsible for this difference, it seems more likely that atmospheric absorption and scattering were responsible.

A large plantation of loblolly pine (Pinus taeda L.) and the upper and mid-slope portions of a small ridge covered by mixed deciduous forests were imaged in the Virgilina flightline. The top of the ridge supported a mixed oak-hickory-pine (Quercus spp.-Carya spp.-Pinus spp.) forest and the mid-slope area supported a white oak-tulip poplar-sweet gum (Quercus alba L.-Liriodendron tulipifera L.-Liquidambar styraciflua L.) forest. All spectra extracted from the pine plantation had a broader absorption feature at approximately 1190 nm than did spectra from the two deciduous forests. This absorption feature is in the wavelength region of a minor water absorption band, and it is not clear whether the differences seen are due to atmospheric or plant water content or to something else. Spectra from the mixed oak-hickory-pine forest often had characteristics intermediate to spectra from the pine plantation and the pure hardwoods stands. Typical spectra from these forests are shown in Figure 1.

It was readily apparent that the starting and ending wavelengths for this AIS data set were not the nominal 1200 and 1500 nm. Vegetation spectra from this data set were compared with laboratory spectra, and the starting and ending wavelengths were estimated as 1156 and 1456 nm. The exact position of the absorption feature described above has not been specified because of uncertainty about the exact wavelengths imaged.

The edge of the Silver Valley lead-zinc mine was imaged in a north to south flightline. There was a halo of slightly different color and texture surrounding the mine site in the principal components transformed AIS image. Spectra extracted from this area were not appreciably different from those from surrounding forests of similar composition. The spectra from the halo area had slightly higher overall reflectance; this could be an indication that the vegetation near the mine was drier than the surrounding vegetation on normal soils.

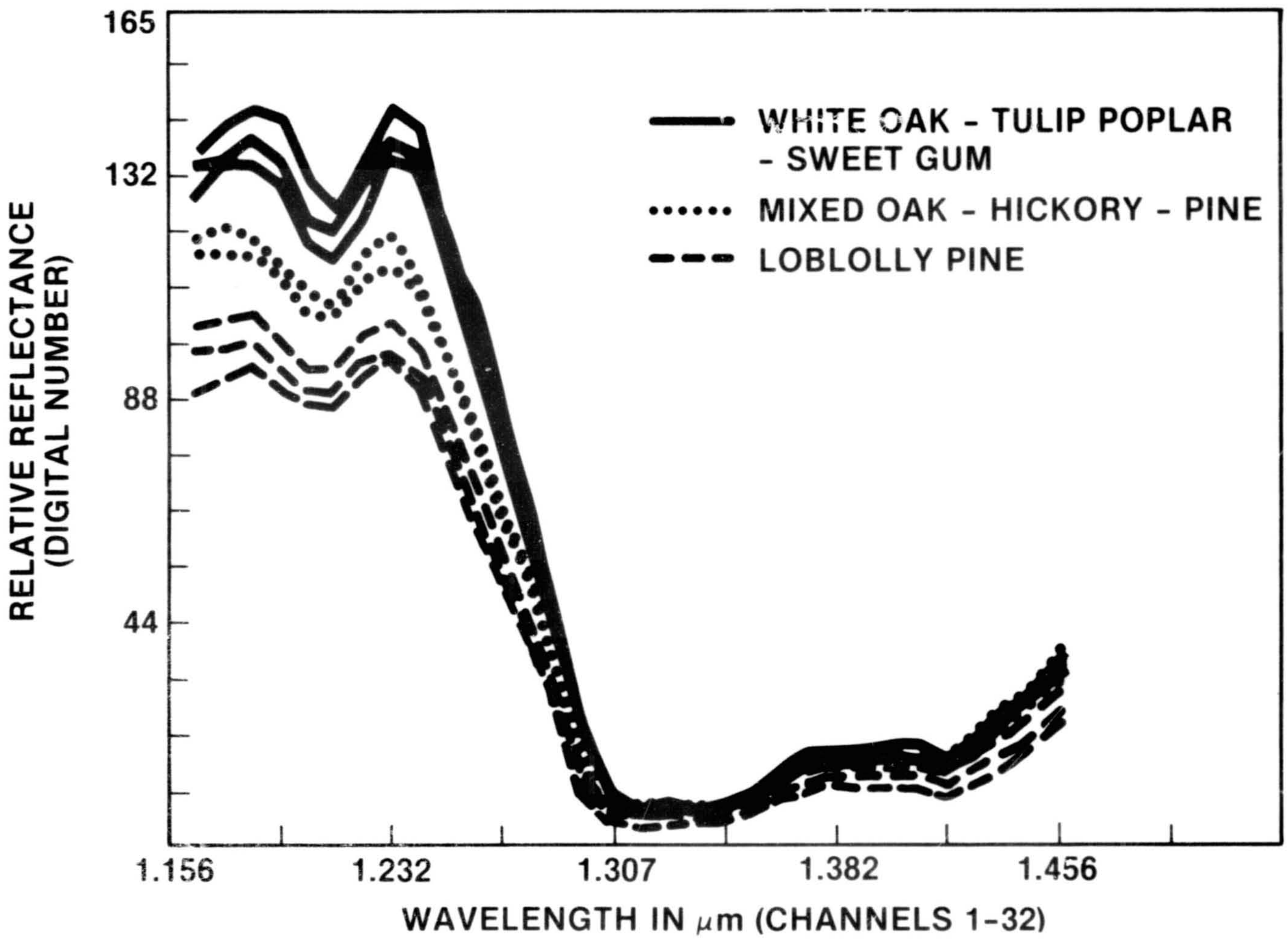

Fig. 1. Typical relative reflectance spectra for forests in the Virgilina area on October 18, 1983. The spectra have been averaged for 3 x 3 pixel areas. The deciduous forests have higher overall reflectance and a narrower absorption feature at approximately 1190 nm than do the evergreen pine forests. The mixed forests have intermediate spectral characteristics.

Spring Imagery

Several small absorption features were noted in vegetation spectra when previewing the spring 128 channel data. Schematic transmission spectra of water vapor and carbon dioxide were superimposed on these plant spectra to identify those atmospheric absorption features which coincided with features in the plant spectra. Carbon dioxide bands at 1575, 1613, 1961, 2020, and 2062 nm and minor water bands at 1190, 1538, 1667, and 2198 nm were evident in the plant spectra. The major water absorption bands at 1400 and 1900 nm matched almost exactly on these superimposed spectra. The water bands for water and vegetation spectra were aligned with the schematic water bands, and the beginning and ending wavelengths were calculated to be 1220 and 2420 nm. Thus, the absorption feature at about 1900 nm noted in the fall AIS data set could not be evaluated in the spring data set.

Two of the spring AIS flightlines included sites imaged in the fall. The pine plantation and mixed deciduous forests in the Virgilina area were imaged; and the edge of the Silver Valley lead-zinc mine site was included, this time on an east to west flightline. The main differences noted among the various vegetation cover types were all related to relative reflectance. Bare fields were most reflective, deciduous forests were intermediate, and pine forests were the least reflective. This was also the pattern for the 1156-1456 nm fall data set. Again, the halo area around the Silver Valley mine site had a slightly higher overall reflectance than surrounding vegetation of the same type. It was not possible to evaluate small differences in plant spectra; they could have been due to atmospheric phenomena, noise, or actual plant differences.

CONCLUSIONS

The width of an absorption feature at approximately 1900 nm was related to differences between evergreen and deciduous forest types in the fall AIS data set. Because atmospheric effects have not been removed from the data, no further conclusions could be made. Removal of atmospheric effects, due to both gases and particulates, must be an important priority for future analysis of AIS data sets.

To successfully evaluate differences in vegetation spectra, which are often small and subtle, new techniques for spectral analysis are needed. Those which have been successfully applied to mineral spectra do not work with vegetation spectra. Clever use of absolute reflectance could be useful. A library of plant reflectance spectra should be prepared. Spectra for plant chemical constituents, such as cellulose, lignin, proteins, and oils, should be included. Mixing models using some of these spectra could yield insights about the nature of vegetation spectra. Also, more study of plant spectral response in the laboratory and the field seems to be necessary before understanding of remotely sensed vegetation spectra will be achieved.

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