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FOREST SPECIES IDENTIFICATION WITH HIGH SPECTRAL RESOLUTION DATA

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ABSTRACT

Data collected over the Sleeping Bear Sand Dunes Test Site and the Saginaw Forest Test Site (Michigan) with the JPL Airborne Imaging Spectrometer and the Collins' Airborne Spectroradiometer are being used for forest species identification. The linear discriminant function has provided higher identification accuracies than have principal components analyses. Highest identification accuracies are obtained in the 450 to 520 nm spectral region. Spectral bands near 1,300, 1,685 and 2,220 nm appear to be important, also.

INTRODUCTION

Reflectance from plant foliage is largely controlled by plant pigments in the spectral region between 400 and 700 nanometers (nm), by internal leaf structure between 750 and 1,000 nm, and by foliar moisture content between 1,200 and 2,400 nm (Knipling, 1967; Olson, 1967; Rohde and Olson, 1971; Tucker 1980). Any biologic or environmental factor that results in a difference in the amount or nature of pigments present in the leaves, in the amount of cell-wall/air interface inside the leaves, or in the moisture content of the leaves can produce a change in reflectance of those leaves. Many investigators have identified differences between species in response to various biological and environmental factors. Thus, it should not be surprising that differences in reflectance between species have been used to distinguish between species (Krinov, 1947; Olson and Good, 1962; Rohde and Olson, 1962; Roller and Thompson, 1972).

Two recent developments in sensor technology have made it possible to further exploit what is known about reflectance from plants: the Collins' Airborne Spectroradiometer (Chiu and Collins, 1978), and the Jet Propulsion Laboratory Airborne Imaging Spectrometer (Vane, et al., 1983). Both instruments provide data with greater spectral resolution (narrower spectral bands) than has been available before. This report is based on investigations with both of these sensors.

METHODS

Data were collected over the Sleeping Bear Sand Dunes and Saginaw Forest Test Sites (Fig. 1) in August 1983. The Airborne Imaging Spectrometer (AIS) flight occurred on 7 August and the Collins' Airborne Spectrometer (CAS) flight on 9 August. No precipitation or other significant weather change occurred between the two flights.

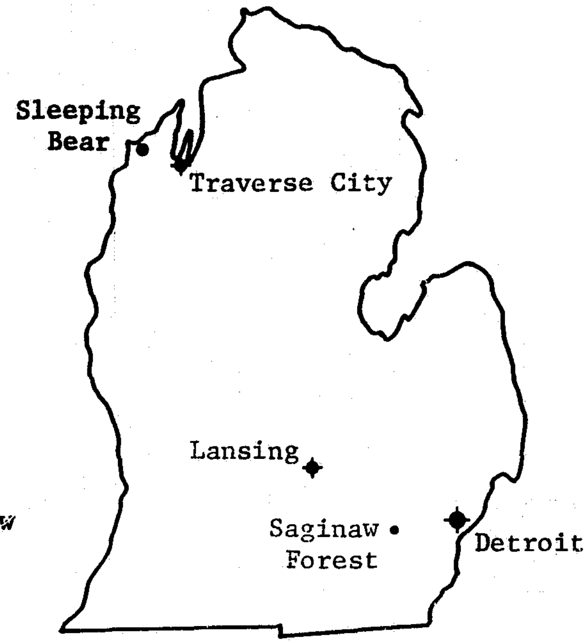

Fig. 1. Locations of the two test sites in Michigan's lower peninsula: Sleeping Bear Sand Dunes northwest of Traverse City, and Saginaw Forest west of Detroit.

The Sleeping Bear Sand Dunes Test Site includes a wide variety of natural and modified cover types on rolling glaciated terrain. The Saginaw Forest Test Site is an 80-acre area five miles west of the University of Michigan campus in Ann Arbor, and largely covered by small plantations of different forest tree species. Because of the relative purity of its individual stands, the Saginaw Forest Test Site was selected for initial analyses of the utility of high spectral resolution data for identifying forest tree species.

Broken cumulus clouds over Saginaw Forest on 7 August prevented acquisition of high quality data with the AIS. High quality data were obtained with the CAS on 9 August. Data analyses were based on six flight lines running essentially north-south, parallel to the long axis of the property. Adequate coverage was obtained for nine cover types: red oak (*Quercus rubra* L.), elm and red maple (*Ulmus spp.* and *Acer rubrum* L.), black walnut (*Juglans nigra* L.), cottonwood (*Populus deltoides* Marsh.), hickory (*Carya spp.*), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* L.(Karst.)), and a small lake. Essentially pure spectra from the interior of each cover type were extracted from the CAS data. Principal component (PC) and linear discriminant function (LDF) analyses were made with these spectra (Zhu, 1984).

Because of the high correlation between reflectances in adjacent spectral bands, and because the size of the data set for the total number of spectral bands (570) exceeded available computer storage, Zhu grouped spectral bands into clusters which he called Band Groups. Band Groups were chosen to correspond to the spectral band widths of six of the Landsat Thematic Mapper (TM) spectral channels. Variations in the width of the TM spectral channels resulted in differences in the number of spectral bands in each Band Group (Table 1), but these differences did not cause problems in the subsequent analyses.

Table 1. Spectral ranges of the Band Groups used in the data analyses and their equivalent Thematic Mapper channels.

Band Group	No. of Bands	Spectral Range (nm)	Equivalent TM Channel
1	48	450-520	1
2	54	520-600	2
3	42	630-690	3
4	136	760-960	4
5	14	1550-1750	5
6	18	2080-2350	7

A PC analysis was performed for the spectra in each Band Group. Those bands within each Band Group having the highest correlations with the first PC axis were selected for subsequent cluster analyses with a PC transformation. An LDF analysis was also used to select optimum bands within each Band Group, and to compare results of Band Groups.

Results of these analyses are being used to guide band selections in analyses of the AIS data for the Sleeping Bear Dunes Test Site.

RESULTS

The PC analyses showed the first principal component accounted for more of the variance in Band Groups 1 through 4 than in Band Groups 5 and 6 (Table 2). When all Band Groups were considered together, the first component accounted for a much lower proportion of the total variance. In every case, however, the first two components accounted for over 95 percent of the variation in the data set.

Table 2. The cumulative variance (in percent) associated with the first and second principal components for Band Groups and for the combination of all Band Groups.

Data Subset	Component 1	Components 1 + 2
Band Group 1	97.72	99.74
Band Group 2	91.72	98.49
Band Group 3	97.61	98.95
Band Group 4	99.86	99.98
Band Group 5	77.43	99.87
Band Group 6	74.52	99.44
Combined	58.85	96.00

Cluster analyses (unsupervised classifications) were performed for each Band Group, for PC selected bands from each Band Group, and for the combined PC selected bands from all Band Groups. One set of analyses considered only three cover classes: water, broadleaved forest, and conifer forest. A second set of analyses considered five cover classes: water; oak, hickory, and walnut; elm and maple; pines; and spruce. Classification accuracy reached 85 percent with the selected bands from Band Group 4 when only three classes were considered, but dropped to 63 percent when the number of classes was increased to five. Because classification accuracies below 80 percent are considered inadequate for most forest resource analyses, PC analyses were not pursued further.

Somewhat better results were obtained with the LDF, and it was decided to attempt a supervised classification with the LDF. The spectra for each cover type were divided into two groups. One group became the training set for that class, and the second group was kept available for testing the classification results. Analyses were made for a two-class case (broadleaved and conifer forests) and for all nine cover classes. As shown in Table 3, results for the combined bands from all Band Groups reached a classification accuracy of 80 percent when all nine classes were considered.

Table 3. Classification accuracies achieved with the linear discriminant function (in percent).

Band Group	Broadleaved/Conifer			All Nine Cover Types		
	Subset 1	Subset 2	All	Subset 1	Subset 2	All
1	83.7	88.1	85.8	91.1	61.2	77.0
2	83.1	90.5	86.8	87.6	51.0	70.4
3	75.5	92.9	83.6	85.7	48.8	68.7
4	79.6	90.5	84.6	87.5	55.0	72.3
5	81.6	90.5	85.7	51.8	40.8	46.6
6	83.7	81.0	82.4	51.8	47.0	49.5
Combined	89.8	*	90.1	94.7	63.2	80.0

* Data not available

These results indicate that data from Band Group 1 (450-520 nm) provide at least as high a capability for discriminating between the forest species included in this test as data from any other Band Group. In fact, when the nine best individual CAS bands were identified, six were in Band Group 1 and one in Band Group 2. The remaining two were in Band Group 5 (1,684 nm) and Band Group 6 (2,222 nm). Both of these latter bands are within the spectral range of the AIS, and suggest that these two bands should be seriously considered in any attempt to identify tree species from AIS data. These results also point to the desirability of expanding the overall spectral band width of the AIS to include spectral bands at wavelengths shorter than 600 nm.

Work at the Sleeping Bear Sand Dunes Test Site was initially focused on early detection of moisture stress with AIS data. In early July, flexible plastic sheds were built beneath the canopies of trenched forested plots, 20x27 meters in size, to prevent rain from reaching the soil. When the AIS data were obtained on 7 August, Scholander pressure cell measurements showed xylem water tensions to be 7.7 bars higher in the stressed maple plot, and 9.0 bars higher in the pine plot, than for the control plots. Comparable data for 9 August, when the CAS data were obtained, showed a xylem water tension more than 9 bars above background for both plots. Foliar moisture content, as a percentage of oven-dry-weight, was 15 percent lower in the stressed maple, and 45 percent lower in pine, than in the controls. Laboratory data for leaves from the maple plot showed a small decrease in reflectance between 900 and 1,300 nm, and a progressively higher reflectance from 1,320 to 2500 nm, as compared to comparable data from the maple control. With pine, the laboratory reflectance data showed a slight decrease in reflectance at wavelengths longer than 1,150 nm.

AIS data were obtained for the stressed plots only in grating position 0. Both plots yielded AIS spectra which differed from spectra for their controls in much the same manner as the laboratory reflectance data. In maple, the reflectance cross-over which was observed at about 1,310 nm in the laboratory data was observed in Channels 15 and 16 of the AIS spectra.

Preliminary results with species identification at the Sleeping Bear Test Site indicate there is probably species information in the spectral region between 1,200 and 1,350 nm. While the moisture stress information is relatively broad-band, it appears that the species information is concentrated in bands about 30 nm wide. The optimum spectral band for separating broadleaved species appears to be approximately 20 nm shorter than the optimum band for separating conifers. A single 50-to-60-nm wide band would probably include reflectance cross-overs which could negate the subtle spectral differences we appear to see in the narrow-band data.

CONCLUSIONS

Based on work completed to date, it seems safe to conclude that high spectral resolution data can provide improved identification of forest tree species from airborne and spaceborne platforms. It also seems safe to conclude:

1. The linear discriminant function is superior to the principal components technique for identification of forest species.

2. There is significant information about tree species in the spectral band between 450 and 520 nm, in the spectral band between 520 and 600 nm, and in spectral bands near 1,300, 1,685 and 2,220 nm.

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