Identification of Two Southern Pine Species in High-Resolution Aerial MSS Data

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ABSTRACT: Aircraft-generated high-resolution Multispectral Scanner (MSS) data were used to evaluate the spectral discrimination of individual longleaf and loblolly pine trees. Training samples centered on specific sunlit crowns were selected to study the spectral reflectance patterns of each species. A simple correlation comparison was used to select the MSS channels best suited for use in a maximum-likelihood classification. Results indicated that the two species could be discriminated on the low-level MSS imagery. No significant difference was found between two-channel and three-channel classifications based on the same sample trees. The near-infrared channel (800 to 890 nm) in combination with a visible channel (650 to 690 nm) was found to be most useful for separation of the subject timber species.

INTRODUCTION

SATELLITE DIGITAL IMAGES are well suited for large area natural resource mapping. However, the radiometric and spatial resolutions of Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data are inadequate for the study of spectral signatures of individual trees. The effects of background reflectance due to bare soil, contrasting ground cover, and mixing of vegetation species can be minimized or avoided by use of high-resolution MSS data. Picture element (pixel) resolutions on the order of those used in this study (0.76- by 0.76-m) would allow spectral sampling of individual tree crowns without the previously mentioned extraneous variation.

In the South, discrimination of various hardwood types from all conifers has generally been the best that could be accomplished with acceptable accuracy (Hill and Evans, 1982; Cannon and Miller, 1974). However, Evans *et al*. (1985) were able to distinguish longleaf - slash pine (*Pinus palustris* Mill. - *P. elliottii* Engelm.) stands from loblolly - shortleaf pine (*P. taeda* L. - *P. echinata* Mill.) stands on National High Altitude Program (NHAP) 1:58,000-scale, color-infrared (CIR) aerial photographs taken in December, 1981.

Numerous factors which affect the spectral separability of forest cover types have been identified. Photographic texture, color, and stand basal area were the primary factors of separability for Onufer (1981). Schade (1976), Smith and Oliver (1974), and Kimes *et al*. (1980) discussed the effect of illumination angle. Rohde and Olson (1972) found it necessary to use only sunlit tree crowns for spectral signature training because of problems associated with target illumination.

Spectral reflectance is also affected by tree and leaf physiological and morphological characteristics. Physiological factors include relative leaf water content, chlorophyll content, and internal structure. These, and morphological characteristics such as needle length and surface area, leaf area index, and crown shape, may vary greatly from tree to tree and from stand to stand due to differences in tree age and vigor as well as site productivity (Murtha, 1972). Reflectance from a plant canopy, although similar to the typical reflectance of the leaves comprising the canopy, is significantly modified by internal shadows, variations in leaf size, orientation and illumination, background reflectance, and plant canopy structure. Murtha (1972) documented the darker appearance of conifers compared to hardwoods on aerial photographs due to the large number of "contained shadows," which are caused primarily by long, narrow, conifer needles and their orientation on branches in the tree crown. Hardwoods, on the other hand, present a more continuous reflecting surface, thus fewer shadows.

The reflectance characteristics of loblolly and longleaf pines may be influenced by the same factors described by Murtha (1972). This project was undertaken to investigate the differences in spectral

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reflectance exhibited by the two tree species. In particular, we were interested in the optimum spectral bands for discrimination between the two.

METHODS

The study area is a 9-ha rectangular tract in Compartment 23 of the Kisatchie Ranger District, Kisatchie National Forest, in Natchitoches Parish, Louisiana (Figure 1). Terrain elevation on the study site varied no more than 10 m. Aircraft MSS data and CIR photography were acquired simultaneously on 22 March 1984 at an altitude of 305-m above average ground elevation. The study area was overflown at 12:00 noon, local time. The sun angle was approximately 60 degrees, which is moderate for the South. The weather was clear with good visibility. A Daedalus model 1260 12-channel scanner (Table 1) and a Jena MRB mapping camera with a 152.4-mm focal length lens were used for data acquisition. Nominal pixel resolution of the scanner was 0.76- by 0.76-m. Kodak Aerochrome 2443 CIR film was used, and the resulting photographs were at a scale of 1:2000. Photographic prints were used for sample-tree location and field work.

FIG. 1. Study area location in Kisatchie Ranger District, Kisatchie National Forest, Louisiana.

TABLE 1. DAEDALUS AIRCRAFT SCANNER SPECTRAL BANDS, CHANNEL DESIGNATIONS, AND ASSOCIATED COLORS, AS USED IN THIS STUDY

Channel	Wavelength (nm)	Color
1	380 – 420	Violet
2	420 – 450	Blue
3	450 – 500	Cyan
4	500 – 550	Green
5	550 – 600	Yellow
6	600 – 650	Orange
7	650 – 690	Red
8	700 – 790	Near Infrared
9	800 – 890	Near Infrared
10	920 – 1100	Near Infrared
11*	310 – 380	Ultraviole (high gain)
12*	310 – 380	Ultraviolet (low gain)

*At the user's option, Channels 11 and 12 may be replaced by Thermal IR data.

SAMPLE SELECTION

Channels 1, 11, and 12 (short wavelength) were not used in this study because they contained excessive image noise. Some of this noise was possibly caused by atmospheric scattering. Another component of the data noise is probably inherent in the design of the scanner. The scanner optics transmit less energy to the detectors for the short wavelengths of energy. Therefore, the detectors for the short wavelengths have to be made larger to capture the same amount of energy. Large detectors inherently produce more noise, which results in a smaller signal-to-noise ratio. The problem with the ultraviolet channels is compounded by the fact that these detectors also have a larger field of view, thereby reducing the resolution and degrading the resulting image quality. Examination of computer-generated electrostatic plots (gray plots) of the short wavelength channels indicated that little, if any, useful information could be obtained from these channels. Plots of the remaining channels (example in Figure 2) showed clearly that tree crowns could be distinguished in these data.

One hundred fifty potential sample pine trees were identified and marked on drafting film overlays of the photographs. The gray-plot of scanner Channel 9 (near-infrared; see Table 1) and the photographs with overlays were then used to select potential sample trees. This technique helped insure that the perimeter of each selected crown could be adequately

FIG. 2. Example of electrostatic plotter output for Channel 9 of the MSS data.

discerned for digital training field selection. All potential sample trees were located within the center one-half of the flight line to minimize the effect of scanner angle perspective. Initially, the species of the 150 sample trees was not known; therefore, an excessive number of potential sample trees was purposely selected so that both species would be adequately represented in the training and test samples. A random set of 87 trees, selected from the 150 potential sample trees, was located in the field and each tree was identified to species.

Computer Processing

Digital processing and analysis were performed with Earth Resources Laboratory Applications Software (ELAS), developed by NASA and modified at the Remote Sensing and Image Processing (RSIP) Laboratory at Louisiana State University. The first step in digital processing was to define a set of statistical training samples which could be used to digitally classify individual tree crowns.

Forty (20 for each species) of the field-identified trees were randomly selected from the original 87 to serve as a training set. The remainder were retained as a test set to determine the accuracy of the computer classification. Pixel samples were selected from the central portion of the sunlit side of the trees (Figure 3). This minimized the effect of crown shading on the resulting spectral information derived from each tree.

Pixels in the general vicinity of each subject tree were replicated (enlarged) on an image display for precise location. The graphic overlay ability of the ELAS software was then used to outline each sample as an eight-pixel polygon and to isolate the spectral data from each channel. These same polygons were later used to test the accuracy of the spectral classification on the training set of crowns.

FIG. 3. Schematic diagram of a pine tree crown, showing spectral sampling method.

Spectral statistics for each polygon were compiled and merged to form a representative spectral signature for each of the two pine species. In this way, potential variance within each species could be incorporated into the two signatures so that an overall spectral definition was obtained for each. Each signature consisted of a mean spectral reflectance value and standard deviation for each channel and covariance and correlation matrices. These signatures were used to categorize (classify) each pixel in the MSS data set with the ELAS maximum likelihood module.

The above sampling and classification technique was intended to determine the true spectral separability, unaffected by background reflectance and crown shadows, of these related timber species. Therefore, other sources of background spectral variation, such as tree shadows and understory vegetation, were excluded from training and classification procedures. Spectral dilution of forest classes by background reflectance and crown shadows in low-resolution pixels may be a significant reason for low classification accuracies in satellite data. Successful spectral recognition of these individual tree species would re-enforce this premise.

Scanner-Channel Selection

After sample selection, a method for selecting the optimum scanner channels was developed based on analysis of simple correlations between the scanner channels. An assumption was made that a minimum of at least one each of the visible and near-infrared channels would contain the most information about the differences in the species classes. Kauth and Thomas (1976) noted that the two visible channels of Landsat data are highly correlated (contain redundant spectral information) as are the two near-infrared channels. Therefore, the intrinsic dimensionality (the smallest number of channels that could represent a Landsat data set accurately) is two. A similar relationship was expected to hold for aircraft MSS data, even though the aircraft MSS has three times as many wavelength bands, and each band has much better radiometric resolution (narrower band widths; Table 1).

The number of scanner channels comprising a signature was minimized to increase the probability of high accuracy with the limited training sample size. As the number of wavelength bands and the number of brightness levels recorded increase, for a fixed number of training samples (in this case, 40), expected classification accuracy reaches a peak and then declines (Landgrebe, 1978). Even though 12 channels of MSS data were available, satisfactory classification accuracy could be expected by selection of fewer, optimally determined, channels.

Studies of imagery types used for vegetation assessment (CIR photography, MSS false-color composites) indicate that a combination of two visible channels and one near-infrared channel is useful for identification of timber species. Coggeshall and Hoffer (1973) suggested that, for cost effectiveness, no more than five channels of MSS data be used: two visible, one near-, one mid-, and one thermal-infrared. Lack of either mid- or thermal-infrared channels in our study reduced the selection problem to that resolved in Table 2.

All possible combinations of two visible channels were compared by correlation to each of the infrared channels. Spectral data from the training and test sets were combined and used to develop the correlations between each pair of channels. The average of three possible pairwise correlations in each three-channel group was used as an indication of information content relative to the represented tree species. The greatest total information could be expected from the channel triplet with the lowest average correlation—Channels 2, 7, and 9—which were selected for the primary emphasis of this project.

Classification and Accuracy

The classification results reported here are intended to illustrate the following:

- Verification of three informative MSS wavelength bands (Daedalus scanner channels) with respect to identification of the subject tree species, and
- Assessment of the variability of individual sample tree reflectance.

Two classifications are reported here to illustrate comparisons between the channels selected. Channels 2, 7, and 9 were used for one classification (Case 1), and Channels 7 and 9 were used for the other (Case 2). Classification was performed with

Table 2. Averages of Three Simple Correlation Coefficients for Triplet Combinations of Two Visible Channels and One Infrared Channel

Visible Channel Pair	Infrared Channel 8	9	10
2,3	0.50	0.39	0.46
2,4	0.51	0.47	0.52
2,5	0.57	0.48	0.52
2,6	0.53	0.42	0.47
2,7	0.47	[0.35]	0.42
3,4	0.71	0.59	0.63
3,5	0.71	0.64	0.63
3,6	0.68	0.55	0.59
3,7	0.63	0.49	0.54
4,5	0.87	0.76	0.77
4,6	0.79	0.66	0.69
4,7	0.70	0.56	0.60
5,6	0.80	0.68	0.71
5,7	0.70	0.58	0.61
6,7	0.69	0.55	0.54

Note: Three correlation coefficients (r values), one for each pair of channels for each cell of the table, were averaged. Correlations were derived from analysis of spectral data from 87 sample trees. Box denotes lowest average (Channels 2, 7, 9).

the Case 2 channels because these closely resembled the red and near-infrared channels present in Landsat MSS and TM data. Both classifications were performed with equal *a priori* values and 95 percent chi-square classification threshold levels for both species.

Classification accuracy was checked by comparing the agreement of the computer-classified trees with the field verification for both the training and test sets of sample trees. The digital classification phase of this project was performed to yield information about species signatures and individual tree variability. All accuracy values (Table 3) were derived by tabulating correctly versus incorrectly classified pixels within the training, test, and combined (overall) sets of sample trees. Only the tree crown pixels within the sample polygons were used in the accuracy determination.

RESULTS AND DISCUSSION

The most accurate classification, both species considered, was 75 percent, which was achieved in Case 1 using Channels 2, 7, and 9, the channels with the lowest correlation to each other and to all other channels. However, Case 2, which utilized only Channels 7 and 9, achieved the same (statistically equal) number of correctly classified pixels (74 percent). Analysis of variance between the classifications showed no significant difference (0.05 alpha level) in accuracy between the two.

Comparison of the training sample accuracy to the test sample accuracy indicated tree-to-tree spectral variability of the species. Training and test sample accuracy for longleaf exceeded loblolly in both classifications. A decrease in the percentage correctly classified was expected with the respective test samples. However, longleaf accuracy increased for the test set in Case 2 and only fell by one percent for Case 1. Because the extendability of a classification signature from a training sample to a test sample depends primarily on the uniformity of reflectance from crown to crown, it is apparent that, for the trees considered in this study, loblolly crowns vary more from tree to tree than do longleaf crowns.

Table 3. Summary of Percent Correct Classification, Pixel-by-Pixel, for Classification Products

Species and sample set	Case 1 (Chs. 2, 7, and 9)	Case 2 (Chs. 7 and 9)
Longleaf pine		
Training set	81	78
Test set	80	85
Combined sets	81	82
Loblolly pine		
Training set	72	68
Test set	64	64
Combined sets	68	66
Overall agreement	75	74

Three-dimensional plots of the reflectance characteristics of two representative trees (height represents relative magnitude of reflectance) show that, particularly in Channel 9, longleaf is more reflective than loblolly (Figure 4). The reflectance of a longleaf pine crown generally falls from a single, high-reflectance peak, while loblolly crown reflectance tends to have more areas of reduced reflectance within the crown, indicating more internal shadows.

Several phenomena probably contribute to the different reflectance properties of these pine species. Apparently, needle and crown morphology combine to cause distinctive spectral signatures. Murtha (1972) stated that "Foliage shape, size, and arrangement influence spectral reflectance since the quantity of contained shadows apparently contributes more to decreased reflectance than do changes in internal leaf structure or cellular content." Harlow and Harrar (1969) describe longleaf pine as having 20- to 46-cm-long needles which are densely tufted at the ends of stout branch tips. Loblolly pine, on the other hand, has stiff, 15- to 23-cm-long needles which are borne closer, and in some cases nearly parallel, to the branch. The tufted arrangement of the longleaf needles presents, in aggregate for the whole crown, a more diffuse reflecting surface. Conversely, the loblolly needle arrangment reflects more incoming radiation down into the crown, resulting in internal crown shadows and both lower overall reflectance and more variable reflectance across the crown.

Kimes *et al.* (1980) noted that variations in reflectance of lodgepole pine (*P. contorta* Dougl.) may be caused by the perspective angle in conjunction with leaf area. With the assumption that needle size and arrangement were the likely determinants of the variation in spectral response by the species of interest, it appears that the misclassified loblolly pines deviated from the training set pines in terms of loblolly needle display and leaf area, resulting in inconsistent spectral reflectance. Considerable deviation in both leaf parameters was noted for the loblolly sample trees during the field study portion of the project. These observed morphological characteristics explain why the classification results indicated a tendency for greater spectral variability between loblolly crowns than between longleaf crowns. Longleaf crowns were observed in the field to consistently display typical needle-length and morphology for the species. Loblolly, however, was observed to vary considerably from tree to tree, not only in the needle length and arrangements, but in the density of needles on individual branches and in an entire crown. These observations are consistent with those of Evans *et al.* (1985), who found that southern pine stands grouped by needle length could be distinguished on CIR NHAP photography.

The moderate sun elevation angle condition existing at the time of imaging also may have contributed to species discrimination. In this case, although overall reflectance decreased for both species, the difference in needle length and arrangement, as well as leaf density, of the two species apparently resulted in a different relative reflectance. As suggested above, longleaf crowns seem to be more diffuse reflectors in the aggregate because of needle length and arrangement.

The purpose of this project was to offer basic insights into the potential for spectral separation of individual trees of the two pine species. Elimination of sources of background reflectance was necessary to determine if there was any basis for separating the trees on an individual level. This approach provided some explanation for limited results obtained from lower resolution data for forest type mapping. The channel selection process used in this study could be used for analysis of lower-resolution aircraft or satellite MSS data.

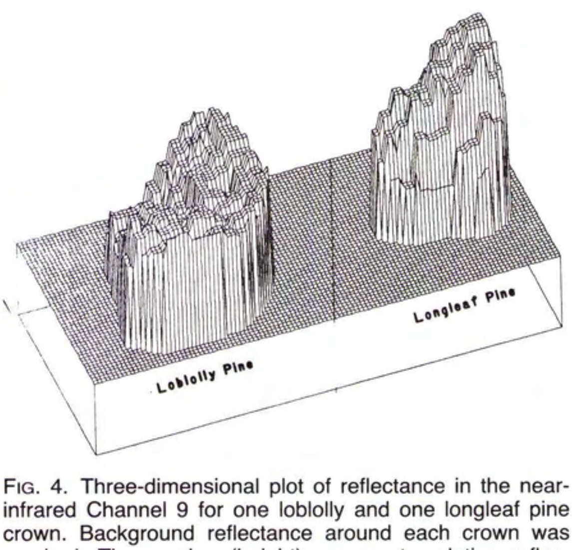

FIG. 4. Three-dimensional plot of reflectance in the near-infrared Channel 9 for one loblolly and one longleaf pine crown. Background reflectance around each crown was masked. The *z*-value (height) represents relative reflectance; *x* and *y* values are element and line locations in an ELAS-format MSS image file.

CONCLUSIONS

Digital spectral classification of low-level MSS data was successfully used to discriminate between loblolly and longleaf pines in a west-central Louisiana study area. Comparisons of between-channel correlations and analysis of variance between classifications demonstrated that no more than two channels could spectrally define the two species. The near-infrared channel (800 to 890 nm) in combination with a visible channel (650 to 690 nm) was found to be most useful for separation of longleaf pine from loblolly pine. A combination of moderate sun (illumination) angle, and tree and crown morphology apparently produced differences in the reflectance properties of the two species. Evidence from this study indicates that the reflectance characteristics are less consistent from tree-to-tree for loblolly than for longleaf pine.

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