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Pecora 10

REMOTE SENSING IN
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PROCEEDINGS

August 20, 21, 22, 1985
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INTERPRETATION OF FOREST COVER ON MICROWAVE AND OPTICAL SATELLITE IMAGERY

P.W. Mueller, D.F. Lozano-Garcia, and R.M. Hoffer
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana 47907

ABSTRACT

The two major portions of the electromagnetic spectrum utilized in remote sensing are the optical and microwave regions. The first Thematic Mapper (TM) -- a new generation optical scanner -- was launched in 1982, which obtained multispectral data in the visible, near infrared, middle infrared, and thermal infrared wavelengths. In October 1984, the Shuttle Imaging Radar-B sensor (SIR-B) was operated from the cargo bay of the Space Shuttle orbiter Challenger and collected L-band synthetic aperture radar imagery at various incidence angles. The SIR-B sensor operated at a 23.5 cm wavelength (microwave region) with an HH polarization. Both SIR-B and TM data were acquired for a predominantly forested area of northeastern Florida. On October 9, 10, and 11, 1984, three different sets of radar data were acquired, each at a different incidence angle -- 28°, 45°, and 58°. The TM data utilized in the study were acquired October 12, 1984.

This study investigated the information content of the various TM Bands and the three SIR-B incidence-angle data sets acquired for this site. Digital techniques were used to produce enhanced imagery which was studied to determine the utility and importance of the various bands and look-angles as they pertain to forest resources. The results indicate that both the optical and microwave portions of the electromagnetic spectrum provide a variety of information about the forest and other cover types present.

INTRODUCTION

With the launch of Landsat-1 in July 1972, man entered a new era for obtaining information about earth resources. Landsat-1 was the first unmanned satellite designed specifically for collecting data about earth resources on a global, repetitive, multispectral basis. Since 1972, numerous studies -- including those by Hoffer et al. (1973), Kalensky and Scherk (1975), and Strahler et al. (1978) -- have demonstrated the effectiveness of computer-aided analysis of optical Multispectral Scanner (MSS) data acquired by the Landsat satellites. In 1982, a new generation optical scanner -- the Thematic Mapper (TM) -- was launched, thereby providing multispectral data with greater spectral dimensionality, finer spectral resolution, and finer spatial resolution than the MSS sensor.

Two major regions of the electromagnetic (EM) spectrum -- optical and microwave -- can be utilized for remote sensing of the Earth's surface. The optical region includes ultraviolet (UV), visible, reflective infrared, and thermal infrared energy, and ranges from approximately 0.3 µm to 14 µm. The microwave region is characterized by much longer wavelengths -- 1 mm to 1 m (Lillesand and Kiefer 1979). Usually, only the region from approximately 0.8 cm to 25 cm is utilized with radar sensor systems. Remote sensing systems operating in the microwave region of the electromagnetic spectrum, such as synthetic aperture radar (SAR), offer some unique advantages over the traditionally utilized optical systems. Because SAR systems are active sensors -- both transmitting and receiving the microwave signal -- they are not dependent on solar illumination. Additionally, the radar signal can penetrate cloud cover which often hinders the acquisition of optical data for forest cover mapping in tropical regions. The Shuttle Imaging Radar-B (SIR-B), which operated in October 1984, was the third spaceborne SAR, being preceeded by the Seasat SAR in 1978, and SIR-A in 1981.

Data acquired by satellite remote sensors of the Earth's surface can provide valuable information to resource managers. The synoptic view provided by these sensors enables the user to detect macro-details for large geographic areas which would be missed when utilizing lower-altitude sensor systems. With the introduction of satellite sensors, multi-parameter data sets were possible. These parameters include date, spectral bands, polarization, incidence angle, etc. By obtaining measurements of the energy reflected or emitted in various wavelength regions (i.e., spectral bands) for earth surface materials, broad classes can be discriminated. Analyzing the data in a digital format allows one to enhance the imagery and also to statistically characterize and classify the data.

OBJECTIVE

The purpose of this study was to investigate the utility of various optical wavelength regions and L-band synthetic aperture radar data acquired at different incidence angles for identifying broad cover types. Interpretation of the individual optical waveband and radar incidence-angle images were conducted and various cover types were digitally characterized.

STUDY SITE

The study site is located in Baker County, Florida (Figure 1). The dominant cultural feature in the study site is the highway intersection of Interstate 10 and U.S. 90 which is located approximately 30 km south of the Okefenokee Swamp and 55 km west of Jacksonville. This highway intersection is evident in Figures 2 and 3. Soils of the area are predominantly sandy and the topography is relatively flat with the elevation ranging from approximately 27 to 53 meters above mean sea level.

The study site is largely forest, with ownership principally divided between Champion International Corporation,

Figure 1. Location of the Forestry Test Site in the State of Florida

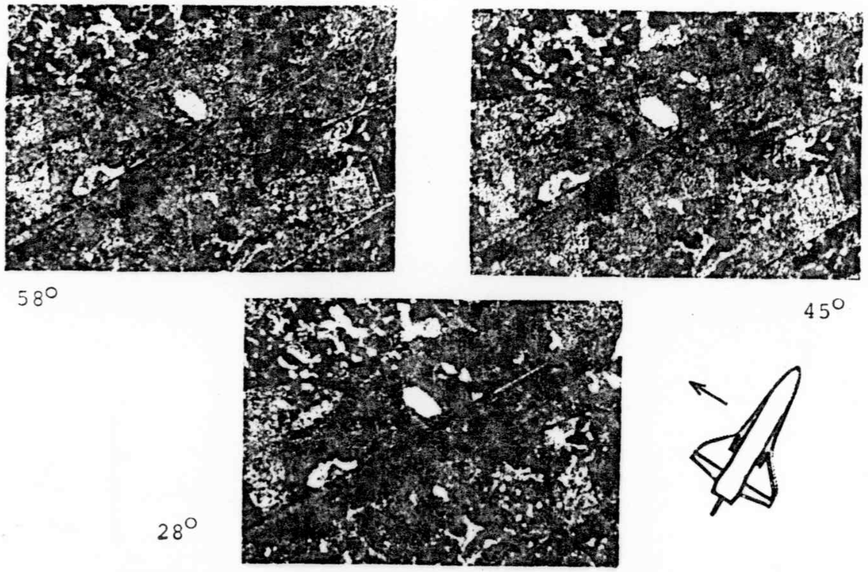

Figure 2. Example of Shuttle Imaging Radar-B Imagery acquired at three different incidence angles (58°, 45°, and 28°) for the Florida Forestry Test Site. See Figure 3.

Owens-Illinois Corporation, Southern Resin and Chemical Company, and the U.S. Department of Agriculture Forest Service (Osceola National Forest). The major forest cover types are pine flatwoods, cypress swamps, and cypress-tupelo swamps. The pine flatwoods are composed of slash pine (*Pinus elliottii*) and/or longleaf pine (*P. palustris*), the former often in plantations. Pine is managed for sawtimber with a rotation age of 50 years on the Osceola National Forest, while it is managed for pulpwood with a rotation age of 25 to 30 years on land owned by the three forest product companies. The cypress and cypress-tupelo swamps largely consist of such deciduous species as pondcypress (*Taxodium distichum* var. *nutans*), baldcypress (*T. distichum*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), water tupelo (*N. aquatica*), black tupelo (*N. sylvatica*), sweetbay (*Magnolia virginiana*), red maple (*Acer*

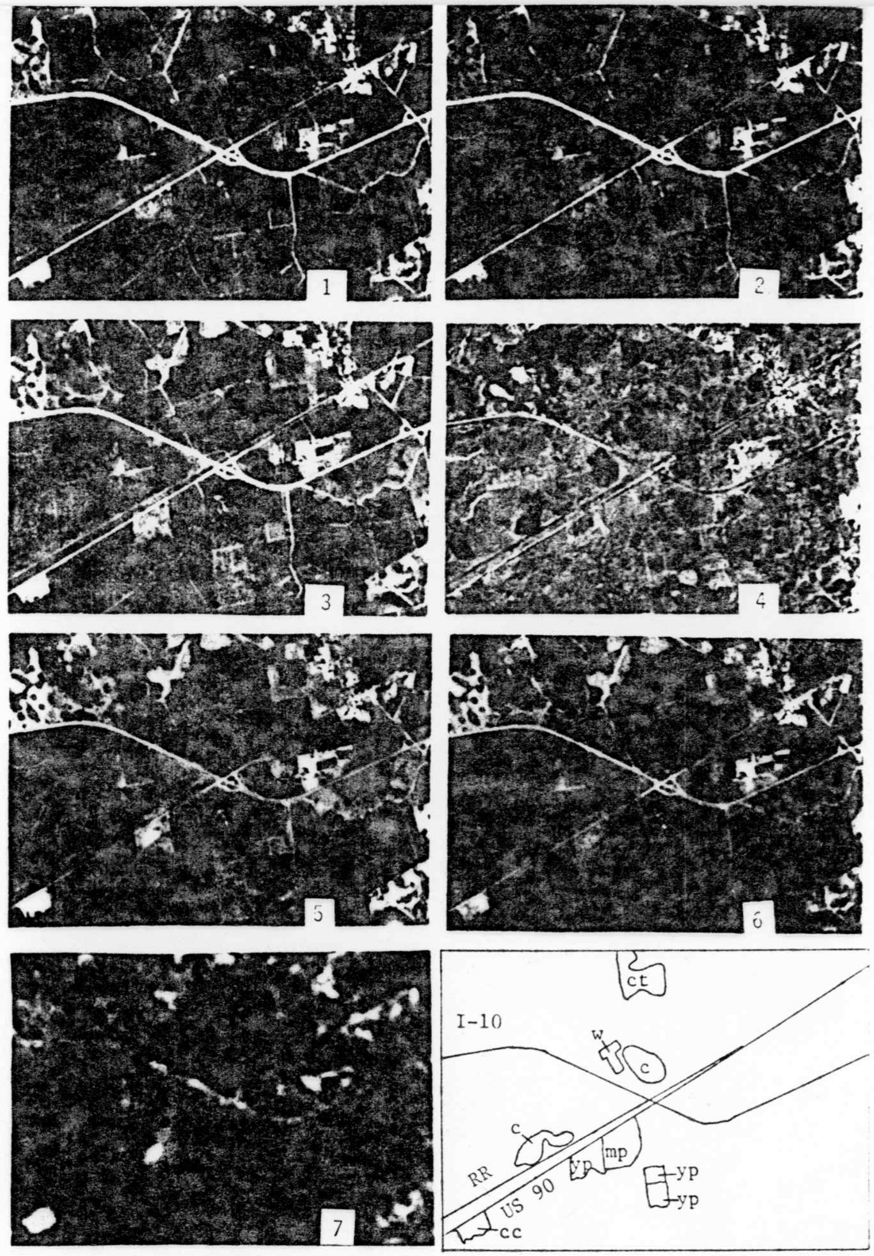

Figure 3. Example of Landsat-5 Thematic Mapper Imagery for the Florida Forestry Test Site. Key: c = cypress swamp; cc = recent clearcut; ct = cypress-tupelo swamp; mp = medium-age pine; rr = railroad tracks; yp = young pine; w = water. TM Bands as indicated.

rubrum), and sweetgum (Liquidambar styraciflua), often with some scattered slash pine and/or pond pine (P. serotina). The cypress swamps are distinguished from the cypress-tupelo swamps in that the former are predominantly pondcypress and baldcypress.

MATERIALS AND METHODS

The optical data utilized in this study was obtained by the Landsat-5 Thematic Mapper sensor which collects data in seven spectral bands as outlined in Table 1. The data obtained in the microwave portion of the EM spectrum was acquired by the Shuttle Imaging Radar-B (SIR-B) sensor which was aboard Space Shuttle Flight 41-G. The TM sensor collected data at different optical wavelengths, whereas the SIR-B sensor data was all collected at the same wavelength, but with different viewing geometries.

Table 1. Characteristics of the Landsat Thematic Mapper sensor and the digital data for the Florida forestry test site. (Adapted from Freden and Gordon, 1983.)

Spectral Band Designation	Wavelength Range (Micrometers)	Spectral Region	Ground IFOV	Pixel Size
TM 1	0.45 - 0.52	Visible blue	30 m	28.5 m
TM 2	0.52 - 0.60	Visible green	30 m	28.5 m
TM 3	0.63 - 0.69	Visible red	30 m	28.5 m
TM 4	0.76 - 0.90	Near infrared	30 m	28.5 m
TM 5	1.55 - 1.75	Middle infrared	30 m	28.5 m
TM 6	2.08 - 2.35	Middle infrared	30 m	28.5 m
TM 7	10.40 - 12.50	Thermal infrared	120 m	28.5 m

Acquisition date	12 October 1984
World Reference System	
Path	17
Row	39
Scene ID number	5022 515311 FL
Platform altitude	705 km
Center incidence angle	0 degrees
Quantization levels	256

The SIR-B data were acquired on the three consecutive days, October 9-11, 1984. The characteristics of the SIR-B data utilized in this study are summarized in Table 2. The repeat cycle for imaging an area was approximately 24 hours with a slight westward drift of the orbital track.

The SIR-B sensor had a tiltable antenna which enabled the same area to be imaged on different passes. Consequently, the viewing geometry of the SIR-B sensor was altered with each orbital pass. Figure 4 illustrates the generalized

Table 2. Characteristics of the digitally correlated SIR-B data for the Florida forestry test site.

Parameter	Value		
Center incidence angle	58.4^{o}	45.3^{o}	28.4^{o}
Acquisition date	9 OCT 84	10 OCT 84	11 OCT 84
Center acquisition time: GMT	0934	0917	0900
EDT	0534	0517	0500
Data take scene number	AK-064.2-003	AK-080.2-003	AK-96.2-003
Orbital track (from true north)	45.0^{o}	45.0^{o}	45.6^{o}
Platform altitude	229.45 km	230.12 km	225.67 km
Slant range to near edge	409.81 km	311.37 km	249.46 km
Center resolution (ground range x azimuth)	16.5 m x 31.5 m	19.8 m x 34.1 m	29.6 m x 25.5 m
Pixel size	12.5 m x 12.5 m	12.5 m x 12.5 m	12.5 m x 12.5 m
Quantization levels	256	256	256
Wavelength	23.5 cm	23.5 cm	23.5 cm
Polarization	HH	HH	HH

viewing geometry of the SIR-B sensor for the three data acquisitions. The three SIR-B data sets were obtained at center incidence angles of 58°, 45°, and 28°. Incidence angle is measured at the target and is defined as the angle the radar beam makes with the surface vertical, where the surface vertical is an imaginary line that passes through the center of the earth. The SIR-B data were digitally correlated and the three data sets were registered at the NASA Jet Propulsion Laboratory.

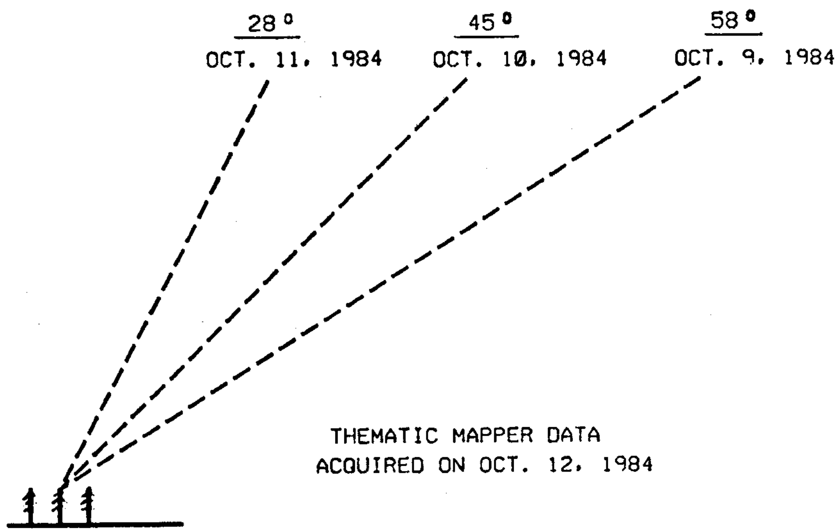

Figure 4. SIR-B multiple incidence angle data set for the Florida Forestry Test Site.

The characteristics of the TM data are listed in Table 1. The acquisition date was October 12, 1984, just one day after the last SIR-B overpass. Data were obtained in four major portions of the EM optical region -- visible, near infrared, middle infrared, and thermal infrared. No clouds were present over the study site.

Qualitative interpretations of the ten images -- three SIR-B and seven TM -- were conducted to characterize the data. The interpretation of digital imagery is similar to aerial photo interpretation using tone, texture, shape, pattern, size, shadow, and association as interpretive clues. Tone and texture are the major factors to consider when developing interpretive keys for forest typing of radar images (Knowlton and Hoffer 1981; Morain 1980). Because these two characteristics are also important for interpretation of optical images, both tone and texture were noted for several broad cover type classes when interpreting the ten images. The broad cover types (non-exhaustive) of interest included water, two classes of deciduous forest, three classes of pine, clearcut areas,

pasture, bare soil, and roads (Table 3). Tone was classified as white, light gray, gray, dark gray, or black; and texture was classified as smooth, medium, rough, or mottled.

Table 3. Description of cover type classes utilized in both the qualitative and quantitative investigations.

Cover Type Class	Description[1]
WATER	Exposed water body
DECID1	Cypress swamp
DECID2	Cypress-tupelo swamp
PINE1	Young pine plantation, 3 - 5 years old
PINE2	Medium-age pine, 25 - 30 years old
PINE3	Older pine, 51 - 52 years old
CLEARCUT	Recently harvested forest area
PASTURE	Non-forested grazing area
SOIL	Bare soil

[1]Forest types described in text under Study Site.

The images that were interpreted were displayed on the IBM 7350 High Level Image Processing System digital display. The images were digitally enhanced using different histogram techniques. Imagery from two sensors are shown in Figures 2 and 3. These images are a sampling of the entire set of data analyzed in this study.

Secondly, to develop a quantitative understanding of the digital data, first order statistics were generated for the nine broad cover type classes. At least three data blocks were selected for each cover type class in a supervised manner for each data type. For each of the ten image data sets, the mean and standard deviation were calculated for each class. These results were then used to quantitatively verify the qualitative analysis results.

Reference data for the interpretation of the SIR-B and TM images included aerial and ground photography, field notes, and forest stand inventory information. The aerial photography included both oblique and vertical photographs. Complete vertical color infrared photographic (1:100,000) coverage of the study site was obtained in September 1984. Additionally, 1:58,000 color infrared vertical photography was obtained in 1983 and 1984 as part of the National High Altitude Photography program. In October 1984, when the SIR-B sensor was operating aboard the orbiter Challenger during Space Shuttle Flight 41-G, 35 mm format color and color infrared photographs of the study site were taken from light aircraft and on the ground as additional reference data. Field trips were made to the study site in August and October 1984, and notes on stand conditions were taken. Detailed stand maps and inventory data were provided by the timberland owners.

RESULTS AND DISCUSSION

Qualitative Interpretation

The results of the image interpretation are summarized in Table 4, where the tone and texture of the nine cover type classes for the ten images are listed. Even though the actual resolution of the SIR-B imagery is higher than that of the Thematic Mapper data, the TM images, except for Band 7 (10.40 - 12.50 µm), were much sharper and features could be recognized more easily than on the SIR-B images. This is primarily due to the speckle characteristics of the SIR-B data and also the side-look view of the radar.

SIR-B. The 28° incidence-angle image provided the maximum amount of differentiation between the general forest classes -- all five classes could be differentiated. This image also had the greatest overall contrast. The 45° incidence-angle image allowed the PINE2 class to be differentiated from PINE3 and DECID2, however, these latter two classes still could not be differentiated effectively. The 58° incidence-angle image had the poorest overall contrast and the three forest classes PINE2, PINE3, and DECID2 were easily confused.

Deciduous swamp forests were highlighted, particularly on the 28° incidence-angle imagery, by a tone of white with light gray or white with gray. Wherever water was standing beneath a forest canopy -- composed of deciduous forest species in all cases observed -- a very bright radar backscatter resulted. This result is similar to the findings of Krohn et al. (1983), MacDonald et al. (1980), and Ormsby et al. (1985) with L-band imagery from other SAR sensors. However, it is not clear from this study whether L-band SAR can be used to discriminate between pine and deciduous forest species when the underlying water is not present, since that situation did not occur to any great extent on this study site; this was not discussed by the authors of the other studies.

In general, relatively smooth surfaces such as WATER, SOIL, and PASTURE were very similar in tone and texture. This is not unexpected since such surfaces act as mirrors, reflecting most of the radar signal away from the sensor resulting in a dark tone.

In some cases, the edges of forest stands were highlighted by a bright strip. This occurred when the trees along the edge of one stand were taller than the trees or other feature in front of them, and the resulting edge was exposed to the radar signal. Thus, the edge of trees formed a "wall" and consequently a corner reflector. This is most evident when forest stands are adjacent to clearings of water bodies, and was most evident on the 58° incidence-angle image, and least apparent on the 28° image. As the incidence angle is increased, the signal is striking the boles of the trees more directly and the return consequently becomes greater.

Table 4. Visual interpretation results for the ten digital images.

Cover Type[1]	SIR-B 28° TON[2]	SIR-B 28° TEX	SIR-B 45° TON	SIR-B 45° TEX	SIR-B 58° TON	SIR-B 58° TEX	TM1 TON	TM1 TEX	TM2 TON	TM2 TEX	TM3 TON	TM3 TEX	TM4 TON	TM4 TEX	TM5 TON	TM5 TEX	TM6 TON	TM6 TEX	TM7 TON	TM7 TEX
WATER	BL	SM	BL	SM	BL-GR	SM-MD	DG	RG-MT	DG-BL	MD	BL-DG	RG	BL	SM	BL	MD	DG-BL	MD	BL-DG	M
DECID1	WH+LG	SM-MD	WH+GR	MD	WH-GR	MD	DG	RG-MT	GR-DG	RG	GR	SM	DG-BL	SM-MD	GR-DG	MD	GR-DG	MD	DG-GR	SM-MD
DECID2	WH+GR	MD	LG	MT	GR	MT	GR-DG	RG	DG	MD	GR-DG	SM-RG	GR-BL	MD-RG	LG-DG	MD	LG-GR	MD	DG-GR	SM-MD
PINE1	BL+GR	SM-MD	BL+LG	SM-MD	BL+GR	MD-RG	GR	RG	LG	RG	LG	MD-RG	GR	MD-RG	LG	MD	LG	RG-MD	LG-GR	SM
PINE2	GR-LG	MT	GR	MT	GR	MT	DG	RG-MT	GR-DG	MD-RG	DG	MD-RG	GR	MD	GR-DG	MD	DG-GR	MD	GR	SM
PINE3	LG	MT	LG	MT	GR	MT	DG	RG-MT	GR-DG	MD-RG	GR	SM-MD	GR	MD	GR-DG	MD	DG-GR	MD	GR	SM
CLEARCUT	BL-GR	RG-MT	BL+GR	MD	BL-GR	MD-RG	LG	RG	WH-LG	RG	WH-LG	SM-MD	DG-BL	RG	WH-LG	MD	WH-LG	SM-MD	LG	SM-MD
PASTURE	BL	SM	BL	SM	BL+GR	MD	GR	MD-RG	LG	MD-RG	LG	MD-RG	WH-LG	MD	WH-LG	MD	LG	MD	LG	MD
SOIL	BL	SM	BL	SM	BL+GR	MD	WH	SM	WH	SM	WH	SM	WH-LG	SM-MD	WH	SM	WH	SM	WH-LG	RG

[1] See Table 3 for explanation.

[2] Key: TON = tone, WH = white, LG = light gray, GR = gray, DG = dark gray, BL = black
TEX = texture, SM = smooth, MD = medium, RG = rough, MT = mottled
- to (a range of tone or texture)
+ with

Thematic Mapper. The relatively smooth cover types so easily confused in the SIR-B imagery were easily differentiated using the TM data. In all the TM Bands, WATER could be differentiated from SOIL and PASTURE. Furthermore, SOIL and PASTURE could also be separated in all the TM Bands, except for Band 4 (near infrared).

Differences were noted between pine and deciduous forest types. However, the swamps were not as strikingly highlighted as they were on the SIR-B imagery. TM Band 4 (0.76 - 0.90 um) was useful for detecting exposed water, but also, water standing beneath forest cover. Many of the forested swamps had a very dark tone on the Band 4 image. Since water has minimal reflectance and vegetation high reflectance in the near infrared, the dark tone may indicate that the trees in these areas were widely spaced or seasonal leaf fall had begun.

The blue visible (Band 1) image had an overall rough texture, which was probably due to atmospheric haze. For this reason, this image was the least desirable of the visible wavelength bands. Cultural features such as roads were most apparent in imagery from Bands 3 (0.63 - 0.69 μm) and 6 (2.08 - 2.35 μm). Even narrow dirt forest roads were readily apparent. On the SIR-B imagery, many of these could not be delineated, even when they cut a swath through forested areas. This inability was probably due to the side-looking geometry of the SIR-B sensor. There is slightly more detail for cultural features provided by Band 3. In addition, Band 3 provides information regarding turbidity of water that Band 6 does not provide. For these reasons, Band 3 was the most valuable visible wavelength Band.

From a visual interpretation standpoint, the Band 7 (thermal infrared) imagery is difficult to analyze due to its poor spatial resolution of 120 m. However, this does not mean that the information is useless. Mueller et al. (1985) report that Band 7 appeared to provide useful information when digitally classifying TM data of forest lands.

Quantitative Analysis

The mean and standard deviation corresponding to each of the nine cover types are shown graphically in Figures 5 and 6, corresponding to the SIR-B and TM data, respectively. One of the advantages of working with digital data is that such statistics can be easily generated. Since the different channels of data from a particular sensor are not absolutely calibrated, interpretation of these plots must be done on a channel by channel basis.

As the digital number value increases for a given channel, the tone on the corresponding image will become brighter and vice versa. When the qualitative interpretation results are compared with these plots, it can be seen that these two methods of characterizing the data gave similar results.

Figures 5 and 6 vividly illustrate the greater variance in

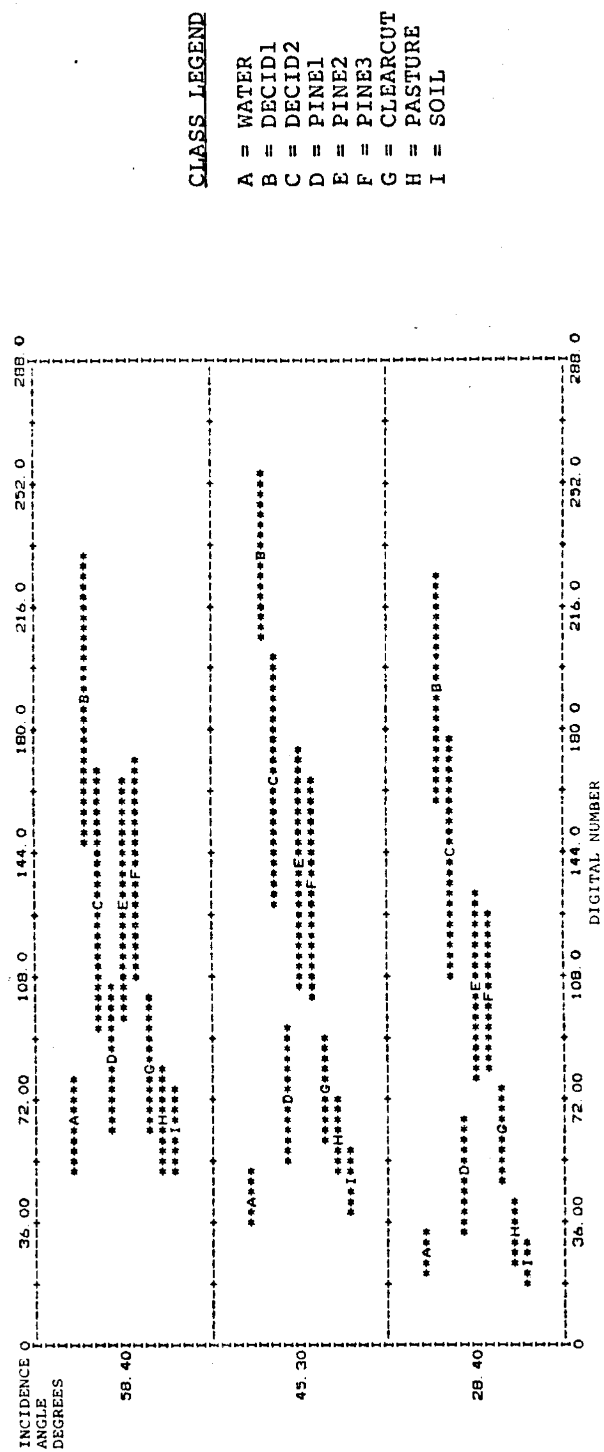

Figure 5. Multiple incidence angle backscatter plot for the SIR-B data. Mean (letter) plus and minus one standard deviation (asterisks) are indicated for each class. Class descriptions in Table 3.

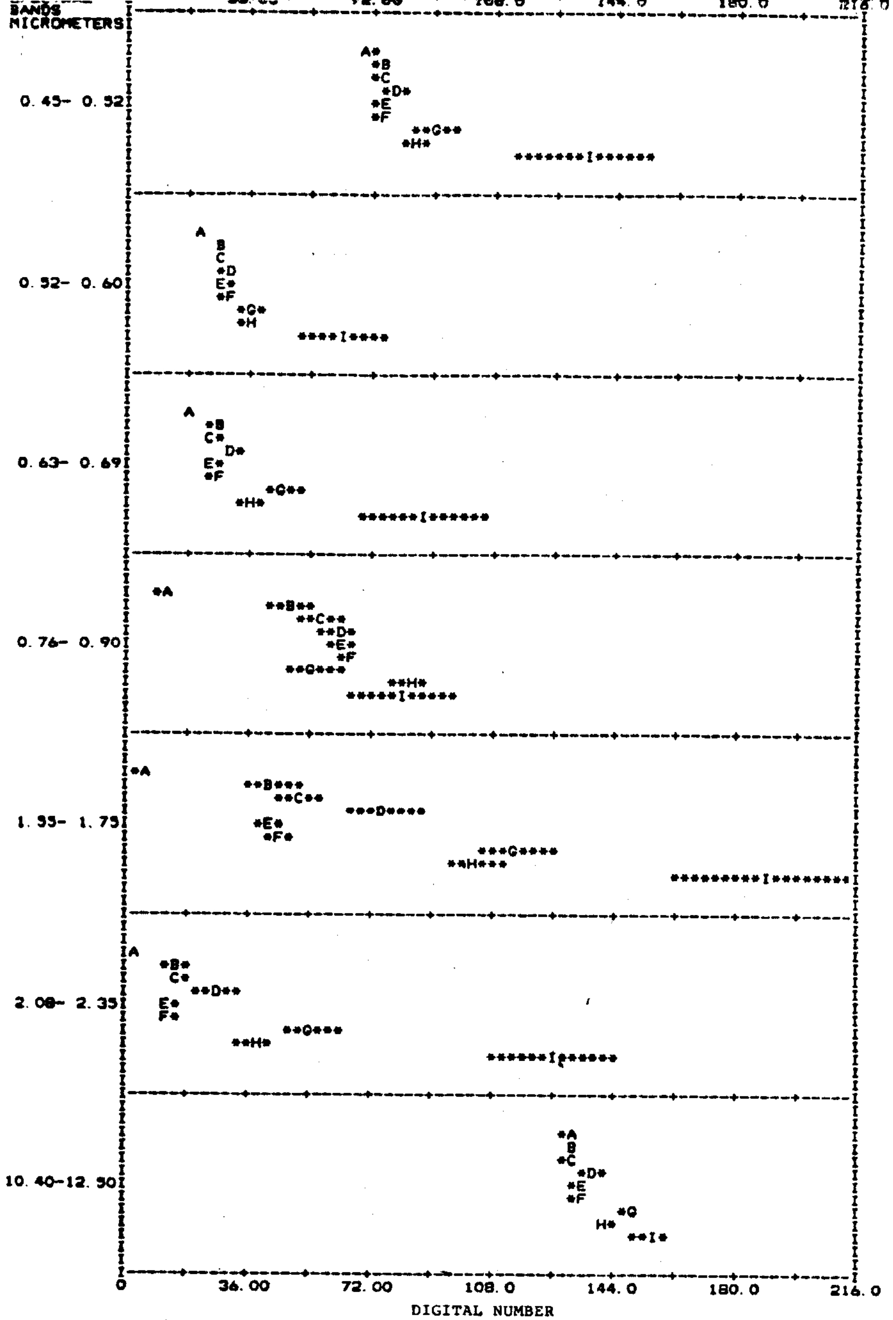

Figure 6. Coincident spectral plot for the TM data. Mean (letter) plus and minus one standard deviation (asterisks) are indicated for each class. See Figure 5 for legend.

the SIR-B data for a single cover type class. This is largely due to the inherent speckle noise, which causes the general lack of clarity in the SIR-B images.

Working with the digital data in a quantitative manner is advantageous because more precise results can be obtained. In further studies, we hope to investigate these two data sets in more detail using computer-aided digital analysis techniques.

CONCLUSIONS

- Even though the SIR-B system resolution was better than that of the TM sensor (except for TM Band 7), the TM imagery had greater detail and clarity.
- On the SIR-B imagery, relatively smooth surfaces such as bare soil, pasture, and water, could not be effectively differentiated, however, with most of the TM images, these cover types could be easily separated.
- Of the ten images analyzed, cultural features were most apparent on the TM Band 3 (0.63 - 0.69 μm) image.
- Of the three SIR-B images, the 28° incidence-angle image provided the maximum amount of differentiation between the general forest classes, present in the study site: young pine, medium-age pine, older pine, cypress swamps, and cypress-tupelo swamps.
- L-band SAR imagery, particularly if obtained at an incidence angle near 28°, can be used to detect standing water beneath forest vegetation.
- Forest stand edges were highlighted on the SIR-B imagery when the exposed edge was facing the sensor and the trees were of sufficient height to form a "wall".

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