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RADAR IMAGERY FOR FOREST COVER MAPPING

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I. ABSTRACT

Dual-polarized, X-band Synthetic Aperture Radar (SAR) imagery was obtained from an altitude of 60,000 feet over a test area near Camden, South Carolina on June 30, 1980. The objective of this study was to determine, qualitatively, the value of the SAR imagery for identifying various forest cover types. In analyzing the HH and HV polarization images, particular attention was given to the tonal and textural characteristics of the cover types involved.

The analysis of the dual-polarized SAR imagery has shown that certain forest cover features are more easily identified in one polarization than the other, while some features look very similar in both polarizations. In general, the results for this data set have shown that the overall tonal contrast between features was greater on the HH image. Neither polarization was consistently better for identifying the various forest cover types examined. These results suggest the usefulness of a dual-polarized SAR system for mapping forest cover.

II. INTRODUCTION

Tremendous progress has been made over the past decade in demonstrating the potentials and limitations for utilizing data in the optical portion of the electromagnetic spectrum for identifying and mapping various earth surface features, including major forest cover groups (deciduous and coniferous) and individual forest cover types. With the continual improvement and interest of sensors that obtain data at wavelengths beyond the optical portion of the spectrum, (i.e., Synthetic Aperture Radar (SAR) systems), additional data sources are becoming available.

Radar systems have several unique advantages over optical systems. These advantages include the capability to penetrate clouds, to be operated day or night, and to obtain imagery in which the tone and texture characteristics are related to the dielectric constant and physionomic properties of the cover types present. The side-look angle of radar systems also provides some characteristics to the data which are not found in other remote sensor systems. Because of the different and perhaps unique characteristics of radar data, a key question is raised: can radar systems provide more effective data for differentiation of forest cover types and density of forest stands than is obtained in the optical portion of the spectrum? Earlier work in the mid-1960's with K-band imagery showed that some vegetative cover types could be differentiated, and that differences were sometimes apparent in cross-polarized data (Morain and Simonett, 1966, 1967). However, these early studies had not involved X-band data, and did not indicate which polarization provided the best capability for discriminating among forest cover types.

III. OBJECTIVE

The objective of this investigation was to determine, qualitatively, the value of dual-polarized, X-band SAR imagery for identifying various forest cover types.

IV. MATERIALS AND METHODS

A. INFRARED AERIAL PHOTOGRAPHY

The photo-interpretation was conducted using 1:40,000 scale color infrared photography obtained on August 29, 1980. Although some changes had occurred in the agricultural cover types between June 30 when the SAR data had been obtained, the forest cover types obviously would not change, so the difference in collection dates between the SAR imagery and IR photography were not considered to be significant for the purposes of this study.

It should be noted that color IR photography was obtained when the radar data had been collected (June 30) and again on July 2; however, both of these sets of color IR photography contained such a large portion of cloud cover that they could not be effectively utilized for photo-interpretation purposes.

B. SAR IMAGERY

The SAR imagery utilized for the study was obtained by NASA's APO-102 side-looking radar mounted on the RB-57 aircraft. The aircraft was flown at an altitude of 18,000 meters (60,000 feet). Since the radar antenna was mounted on the left side of the aircraft flying to the north so that the look direction was to the west. This created radar shadow effects similar to the sun-shadow effects observed on the photography obtained in mid-morning.

The radar system is a fully focused SAR imaging system. A horizontally polarized pulse of energy of 9600 MHz +/- 5 MHz (commonly known as X-band) is transmitted by the system, with the returning energy being recorded on separate holograms as horizontally (HH) and vertically (HV) polarized responses. These holograms were processed through an optical correlator by Goodyear Aerospace Corporation, under contract to NASA, and the resulting images were recorded on positive film. For these conditions of data collection and processing, the range and azimuth resolutions depicted by the imagery are just under 15 meters. For interpretation purposes, the original transparencies were enlarged to produce positive prints having a scale of both 1:80,000 and 1:50,000, which were then used for the interpretation and analysis.

C. IDENTIFICATION OF FOREST COVER TYPES

Various forest cover types were identified on color infrared photography using standard photo-interpretation techniques supplimented by field observation data. The forest cover types identified on the aerial photography included old growth hardwood, second growth hardwood, water tupelo, pine (primarily slash pine although some areas of long leaf and loblolly pine also occurred). In addition, there were areas where the forest had been clearcut, as well as pasture areas, crop land, areas of exposed agricultural soil, and water features that were identified on the photography.

D. IDENTIFY AND COMPARE FOREST COVER TYPES ON SAR IMAGERY

Based upon the photo interpretation results, stands of the various forest and other cover types were located on both polarizations of SAR imagery. The two polarized images then were analyzed to determine if tonal and/or textural differences existed between the cover types. The tonal characteristics were determined by evaluating the discrete or representative gray tone for each cover type. The textural characteristics were determined by evaluating the relative speckle for each cover type. The tonal and/or textural differences between the HH and HV polarized images then were compared and evaluated for each cover type. An attempt was made to determine why particular differences did occur.

V. RESULTS

The initial analysis of the SAR imagery depicted a banding effect which was particularly noticable on the HH image. A much more subtle tonal variation that seemed to be related to the range angle could be observed, particularly on the HV image. Both of these effects can be observed in Figure 1, which shows the data for both polarizations of the entire flight line. Both effects had a significant impact on the ability of the interpreter to determine various cover types using the radar imagery alone. Both the banding and tonal variation effects were not due to any characteristics of the ground terrain, but were due strictly to variables inherent in this particular data collection and processing system. Both effects were also quite evident on several other data sets obtained at the same time over other flight lines. It should be pointed out that although the HH polarization had greater tonal contrast, the overall lack of contrast of the HV imagery may have been due to the parameters involved in obtaining and processing this particular data set and not necessarily an inherent characteristic of HV polarized imagery.

Deciduous forest cover appears to have a characteristic light tone on the HH image, whereas on the HV image these deciduous areas have a darker tone. This was most evident in the area of the alluvial plain where dense deciduous forest cover was located (see Figure 2). The dense deciduous forest stands located in small ravines were identified on both polarizations due to their distinctive spatial patterns (see Figure 3). These patterns were highlighted because of the high response given by the deciduous forest cover growing within the ravines and perhaps

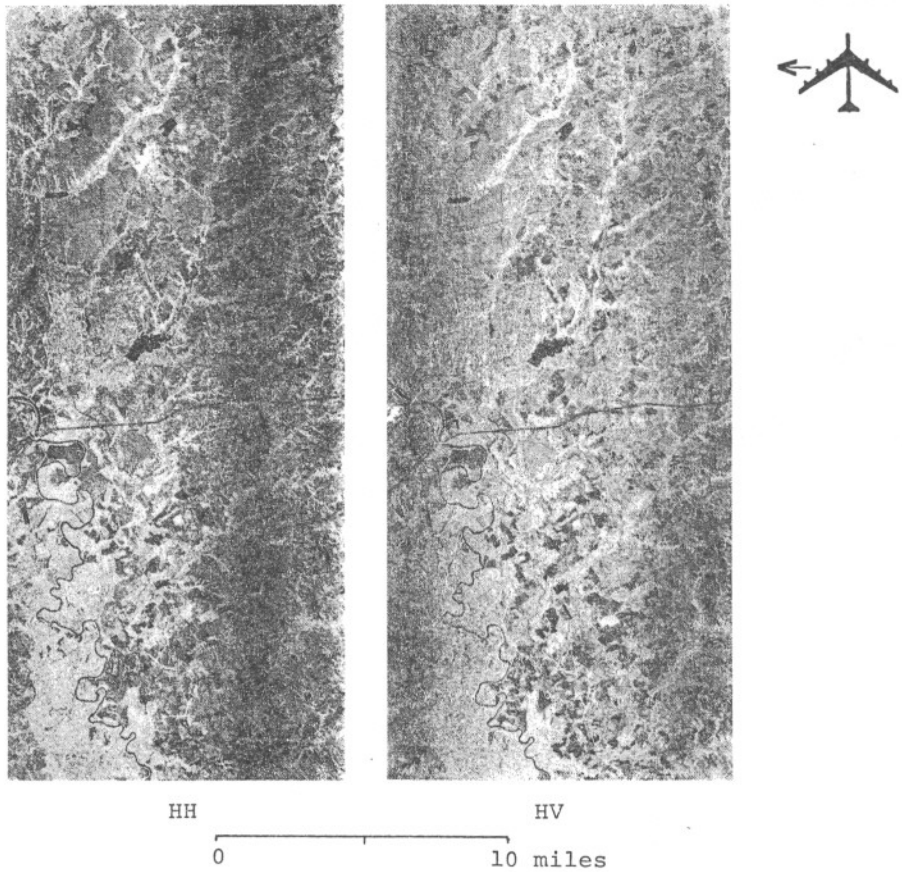

Figure 1. Dual-polarized X-band SAR imagery of the test site near Camden, S.C.

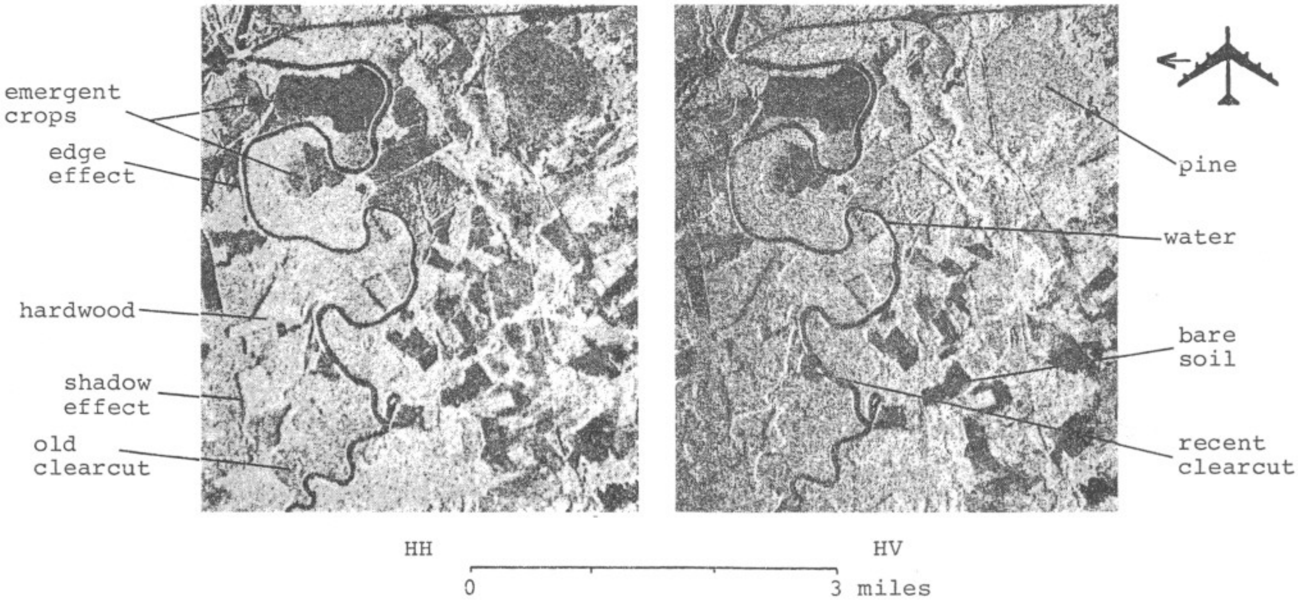

Figure 2. Enlargement of dual-polarized imagery showing tonal differences between deciduous and coniferous forest cover.

also highlighted in part by the slopes of the ravines per se acting as angular reflectors. Due to the contrast difference between the two polarizations these patterns were more distinctive on the HH image than on the HV image.

One of the most distinct differences observed in the imagery was a difference between deciduous and coniferous forest cover that could be observed as a function of polarization. As shown in Figure 2, there is very little difference between deciduous and coniferous forest on the HV image. On the HH image however, the deciduous forest cover has a distinct light tone whereas the coniferous forest cover has a relatively dark tone. Thus, deciduous and coniferous forest cover can be easily separated on the HH image due to the distinctive tonal differences that are very difficult to separate on HV image.

Other features such as older clearcuts and fields having emergent vegetation tend to look very similar in both tone and texture on both polarizations. Although recent clearcuts are very dark in tone in both polarizations as compared to the surrounding forest cover, they are easier to separate from coniferous and mixed cover types on the HV imagery. Water and smooth bare soil features have a distinctive black appearance on both polarizations due to the specular reflectance of the emitted radar signal away from the antenna. However, by using the shapes and speckling characteristics of some agricultural fields, water and fields with bare soil usually can be separated.

It should be noted that of the features identified on the color IR photography, several could not be identified on the SAR imagery. Old growth and second growth hardwood stands could not be separated. Water tupelo was very easy to identify on the color IR photography because of its distinctive color, but could not be identified at all on the SAR imagery. Table 1 summarizes the tonal and textural characteristics of the various forest and other cover types examined in this study. Examples of the tonal and textural characteristics are illustrated in Figure 4.

Table 1. Tone and Texture Characteristics of Various Cover Types in Relation to Polarization of the Radar Imagery.

Cover Type	Tone[1/]		Texture[2/]	
	HH	HV	HH	HV
Hardwood	white	light gray	grainy	grainy
Pine	dark gray	gray	speckled	speckled
Mixed Pine-Hardwood	dark gray	gray	grainy	speckled
Clearcut	dark gray	dark gray	grainy	grainy
Bottomland scrub	dark gray	dark gray	speckled	speckled
Pasture	dark gray	dark gray	grainy	grainy
Emergent Crops	dark gray	dark gray	grainy	grainy
Bare Soil	black	black	smooth	smooth
Water	black	black	smooth	smooth

[1/] Tone: (A) black; (B) dark gray; (C) light gray; (D) white

[2/] Texture: (1) smooth; (2) grainy; (3) speckled

(These letters or numbers indicate the examples of these descriptions shown in Figure 4)

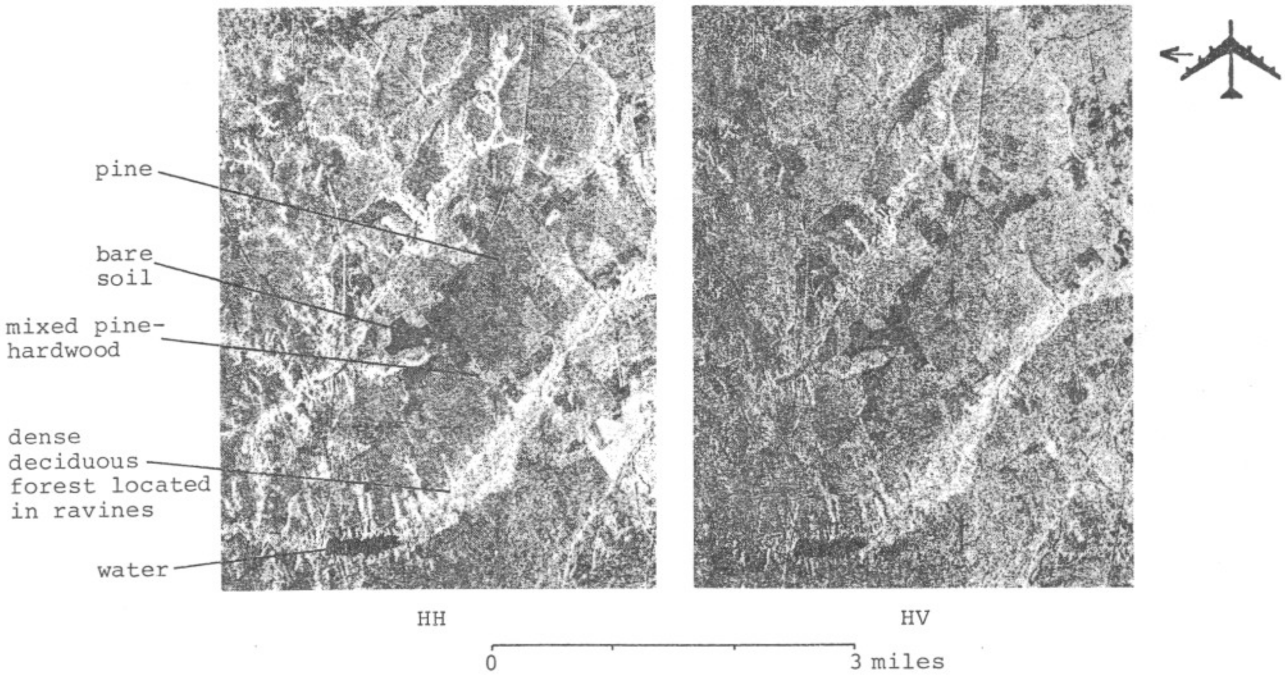

Figure 3. Example of radar imagery indicating distinct apperance of vegetated ravines on HH polarization.

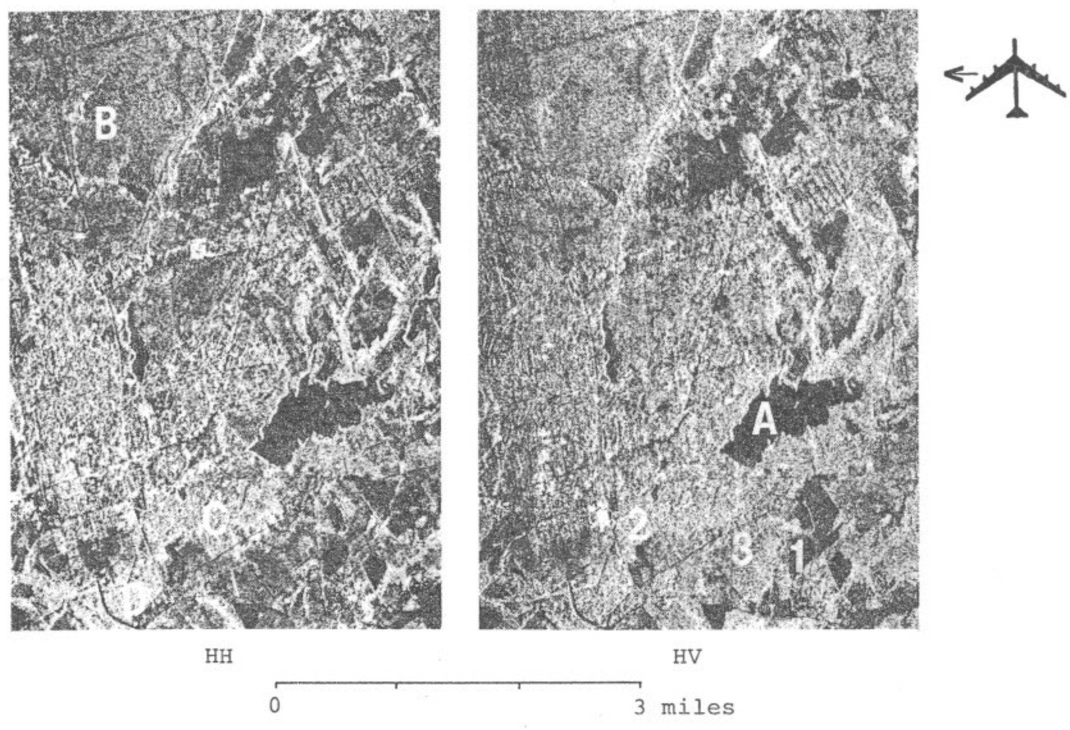

Figure 4. Example of tonal and textural characteristics of SAR data (see Table 1).

VI. SUMMARY AND CONCLUSIONS

The qualitative analysis of the dual-polarized SAR imagery has shown that certain forest cover features are more easily identified in one polarization than the other, while many non-forest features look very similar in both polarizations. Discriminating between coniferous stands and deciduous stands was easier on the HH image than on the HV image. However, this does not infer that the HH polarized image is better. The shadow and edge effect due to extreme differences in vegetation height help delineate the boundaries of clearcuts, and are much more prevalent on the HV image. Neither polarization is consistently better for identifying the various forest cover types examined.

The following points summarize the results obtained during the analysis:

- Deciduous forest cover is easily identified on the HH image due to a distinctive light tone, whereas on the HV image these areas have a darker tone. (Figures 2 and 3)
- Coniferous forest cover is dark in tone on the HH image and is somewhat lighter in tone on the HV image. (Figure 2)
- Deciduous and coniferous forest cover are easily separated on the HH image due to their distinctive tonal differences, but are difficult to separate on the HV image. (Figure 2)
- Dense deciduous forest stands located in ravines are easily identified on both polarizations because of the topographical pattern being highlighted by the response of the deciduous stands and partially highlighted by the slopes acting as angular reflectors. These patterns are more distinctive on the HH image than on the HV image. (Figure 3)
- Older clearcuts and fields having emergent vegetation tend to look very similar in both tone and texture on both polarizations. (Figure 2)
- Water and smooth bare soil features have a distinctive black appearance on both polarizations due to the specular reflectance of the emitted radar signal away from the antenna. (Figure 2)
- There is a distinctive banding effect on the HH image and a tonal variation related to range angle on the HV image which impact the ability of the interpretor to determine various cover types. These effects were also evident on other data sets of different flight lines. (Figure 3)

These results suggest the usefulness of a dual-polarized SAR system for mapping forest cover. The next phase in the analysis of this data will involve digitization of the imagery using a scanning microdensitometer, followed by a quantitative evaluation of a spectral/spatial pattern recognition algorithm (ECHO) to classify forest and other cover types.

VII. REFERENCES

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VIII. ACKNOWLEDGEMENT

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