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Crop Identification with L-Band Radar

The probability of correct classification was about 65 percent with like polarization radar returns; correct classification increased to 71 percent with both like and cross polarization.

ABSTRACT: *The results of a study to discriminate crop types using L-band dual polarization (HH and HV) radar data are reported. The flight was made over Huntington County, Indiana on 13 September 1973 using the Environmental Research Institute of Michigan (ERIM) radar. The test sites included fields of corn and soybeans, woodlands, and continuous-cover vegetation types such as small grains, pastures, and fallow fields.*

The analysis resulted in the following observations:

- *The like (HH) polarization radar return was successful in discriminating between corn and soybeans; however, woods were consistently confused with corn and continuous-cover types with soybeans. The probability of correct classification was about 65 percent.*
- *Use of both like (HH) and cross (HV) polarization components increased the probability of correct classification to 71 percent.*

INTRODUCTION

WITH THE LAUNCHING of Seasat-1, short though its life span was, and with the space Shuttle radar missions anticipated for 1980 and 1981, satellite-acquired radar imagery is slowly becoming more available to the scientific community. The radar system used aboard Seasat-1 and the system to be used aboard the first instrumented Shuttle flight are L-band (1.25 GHz; λ = 23 cm) Synthetic Aperture Radar (SAR) imagers. For ocean surface observations, the Seasat-1 SAR operated at a 70° depression angle and had a ground (or sea surface) resolution of 25 metres. The first Shuttle Imaging Radar (SIR-A) is essentially the same radar but has been slightly modified to provide imagery more appropriate for geological mapping. It will utilize a 6° beamwidth centered at a depression angle of 43° and will have a ground resolution of 40 metres. Although the results of earlier investigations of radar as a crop classifier[1-7] indicate that frequencies above 8 GHz (wavelengths shorter than 3.75 cm) are preferred for crop discrimination, it may nevertheless be desirable, in the future, to evaluate these satellite-borne L-band sensors for potential contributions to cropland inventories. Results of crop classifications based on aircraft-acquired L-band imagery are presented here to show that, while not the optimum sensors, long-wave radar systems may be able to provide useful information about vegetation cover.

MISSION AND TEST SITE PARAMETERS

On 13 September 1973, the Environmental Research Institute of Michigan (ERIM)

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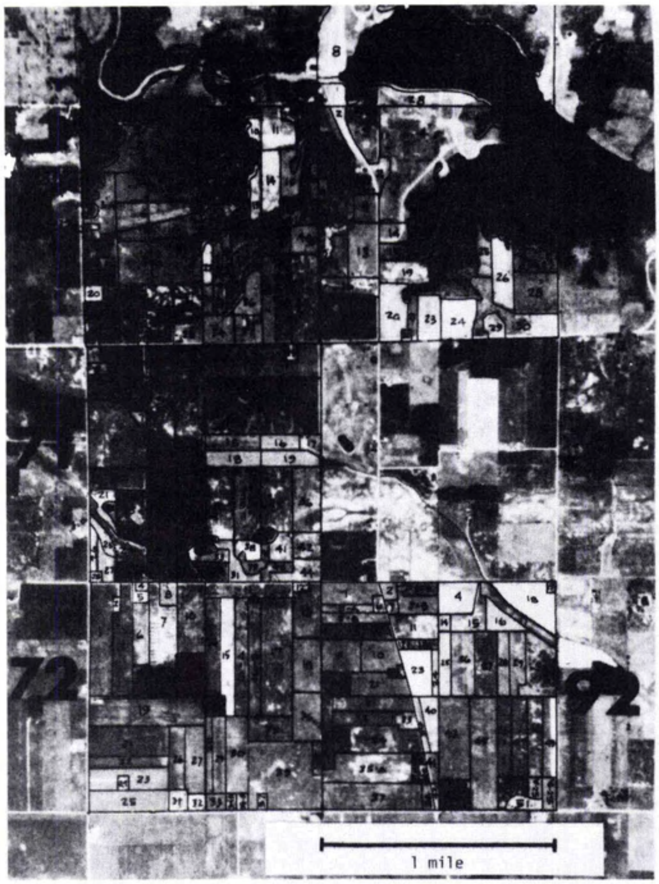

FIG. 1. Aerial photograph and overlay showing representative portion of test site.

synthetic aperture radar was flown over Huntington County, Indiana[8]. The test site was covered by two adjacent passes flown at 2170 metres msl with a swath width of 4500 metres each. L-band imagery with HH and HV polarizations was obtained. Depression angle ranged from 31° in the near range to 15° in the far range. Radar return values were digitized as grey levels (128 steps) for classification purposes.

The areas imaged are located between latitudes 40°41′ N and 40°58′ N and between

TABLE 1. NUMBER OF FIELDS PER CATEGORY FOR PASS 1 AND PASS 2

Pass 1*			Pass 2**		
Crop Type		Number of Fields	Crop Type		Number of Fields
Continuous Cover:			Continuous Cover:		
Fallow	6		Fallow	0	
Grains	5	21	Grains	6	23
Pasture	10		Pasture	17	
Woods		10	Woods		16
Corn		40	Corn		35
Soybeans		42	Soybeans		42
Total		113	Total		116

* 40°33.3′N to 40°58.4′N, 85°26.4′W to 85°29.5′W.
** 40°41′N to 40°58.4′N, 85°29.8′W to 85°33′W.

longitudes 85°26′ W and 85°33′ W. An aerial photograph of a portion of Pass 2, along with an Agricultural Stabilization and Conservation Service (ASCS) overlay indicating field numbers, is shown in Figure 1. Ground truth data included field numbers, crop types, percent cover, and row direction (when applicable). Table 1 indicates the number and kinds of fields imaged. Fallow fields and small grains were eventually combined with pasture for classification since the radar returns for all three categories were similar and there were few fields of each. The corn and soybeans were mature and ready for harvest at the time of the overflight.

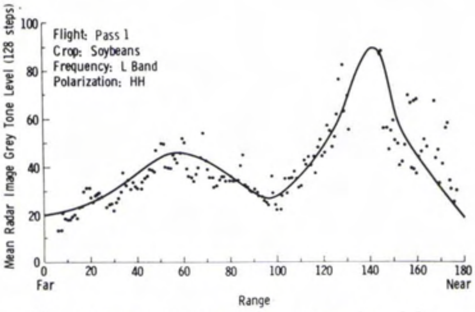

FIG. 2. Mean radar image gray tone level for soybeans as a function of range. The test site was divided into 250 strips parallel to the flight line. (Pass 1)

DATA NORMALIZATION AND AGGREGATION

For an imaging radar, the backscattered return from a given type of target (such as a corn field) changes across the image from the near range to the far range because antenna gain, path loss, and scattering coefficient vary as a function of depression angle. As a first look to inspect the trend of the Indiana data with range, the test site for each pass was broken up into five strips (parallel to the flight line), and from each strip all corn and soybean data were averaged separately and plotted as a function of range. The curves were quite similar in shape for both passes, for HH and HV polarization, and for both corn and soybeans, although corn consistently gave a higher return than soybeans.

To calculate a range correction curve at a higher spatial resolution, each test site was divided into 250 parallel strips, and only the more extensive soybean data were utilized. All soybean pixels within each strip were averaged and plotted and a curve was fitted to their distribution with range. The images from the two passes were processed separately to minimize any biases due to variations in aircraft altitude, although the results for both were quite similar. The range correction curve thus obtained for one of the passes is shown in Figure 2. After normalizing by these curves, the pixels were aggregated into fields, and means and standard deviations were calculated for each field.

CLASSIFICATION RESULTS

To quantify the separability among vegetation types in the Indiana imagery, a linear discriminant analysis[9] was performed on the normalized data. For all of the analyses, 50 percent of the samples were randomly selected for training and the remaining samples were used for testing. The percent of fields correctly classified is calculated as the ratio of the number of training and test fields correctly identified to the total number of fields in a given category.

The classification analysis was performed using each of the two discriminating variables, like polarization (HH) and cross-polarization (HV) returns, singly and in combination. The classification results were about the same for Pass 1 and Pass 2 individually, as well as for the data base consisting of both passes. Results of the classification on the combined data base are provided in Table 2. Among the two variables, HH provides a higher level of correct classification, 64.6 percent. Discriminating with both parameters raises the level to 71.2 percent.

Contingency tables indicating the nature

TABLE 2. DISCRIMINANT ANALYSIS RESULTS FOR THE COMBINED DATA FOR BOTH PASSES, FOUR CROP TYPES

Variable	Classification		Probability of Correct Classification %
	Training Patterns	Test Patterns	
HH	67/107*	70/105	64.6
HV	60/107	67/105	59.9
HH, HV	76/107	75/105	71.2

* 67 out of 107 fields were correctly classified.

TABLE 3. CONTINGENCY TABLES FOR HH AND HH, HV CORRESPONDING TO TABLE 2

One Dimensional Analysis (HH)

Contingency Table for Training

True Category	Woods	Pasture	Corn	Soybeans
Woods	0	0	10	1
Pasture	0	8	1	5
Corn	0	0	24	14
Soybeans	0	2	7	35
	Assigned Category			

Contingency Table for Testing

True Category	Woods	Pasture	Corn	Soybeans
Woods	0	0	10	5
Pasture	0	9	0	4
Corn	0	0	26	11
Soybeans	0	0	5	35
	Assigned Category			

Two Dimensional Analysis (HH, HV)

Contingency Table for Training

True Category	Woods	Pasture	Corn	Soybeans
Woods	3	0	7	1
Pasture	0	11	1	2
Corn	0	0	24	14
Soybeans	0	1	5	38
	Assigned Category			

Contingency Table for Testing

True Category	Woods	Pasture	Corn	Soybeans
Woods	4	0	6	5
Pasture	0	11	0	2
Corn	0	0	25	12
Soybeans	0	1	4	35
	Assigned Category			

and magnitude of misclassifications are given in Table 3. The cross polarization component, HV, when added to the like polarization, permits extraction of seven fields of woods which were previously misclassified as corn when only HH was used. Some improvement is also noted in the continuous cover categories (pasture fallow fields, and small grains).

CONCLUSIONS

Analysis of the Huntington County L-band radar data for crop classification led to the following conclusions:

- The relative radar returns from corn and soybeans at L-band agree with the data reported by Ulaby[4] at 4.7 GHz (2 = 6.4 cm);
- It is possible to separate four categories—corn, soybeans, woods, and continuous cover—with a confidence of 71 percent if both like and cross polarization returns are employed;
- If only one polarization is used, HH yields good overall results (65 percent) and is able to separate corn, soybeans and continuous cover crops; however, woods are consistently confused with corn; and
- The cross polarization component, HV, is able to differentiate woods from other crop types and, if used in conjunction with the like polarization component, improves the overall confidence of prediction by about 10 percent.

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BOOK REVIEWS

Aerial Archaeology. D. A. Edwards and E. A. Horne, eds. London: The Aerial Archaeology Foundation. Volume 2; 95 pages. Price, £5.95 plus 25p packing and postage from Hon. Librarian, The Aerial Archaeology Foundation, 6 Highgate Green, Elton, Peterborough, Cambridgeshire, England, 1978 ISSN 0140-9220.

REMOTE SENSING, particularly the use of aerial photography, has been an integral part of archaeological reconnaissance and discovery in England and Europe for far longer than in the United States. Cultural resources remote sensing today is quite different in the Old and New Worlds, and *Aerial Archaeology* provides an interesting vignette of the nature and possible causes of this variation.

Aerial Archaeology was originally conceived as a newsletter for members of the Committee for Archaeological Aerial Photography (Anglian Region), a coalition of about 30 different governmental and private organizations making use of aerial photography in the discovery, analysis, and recording of prehistoric and historic sites and structures throughout Great Britain. With the publication of Volume II, however, it has become clear that *Aerial Archaeology* is more than a newletter, and should be of interest to all those involved in aerial remote sensing of cultural evidence, prehistoric or not. Well-organized and profusely illustrated, Volume II stands as a tribute to the energy and enthusiasm of aerial archaeologists across the Atlantic.

The publication is initiated by a series of reports from members of the Committee, and divergences from aerial remote sensing of cultural resources in the United States are immediately apparent. England is today the scene of extensive, systematic efforts to catalog, map, and monitor a profusion of archaeological evidence, primarily prehistoric and historic villages, farms, towns, and other structural sites visible through the agency of crop marks and other vegetative evidence. In the United States, of course, very few structural sites of this nature exist, except in the Southwest; and where they do, and have not been obscured by modern land disturbance, vegetation is for the most part natural and not conducive to crop-mark observation. The focus of American archaeology is increasingly trending toward settlement patterns, regional strategies, and ecological explanation rather than structures, an emphasis which calls for small-scale remote sensor imagery and the analysis not of sites but the total environment.

The body of *Aerial Archaeology*, Volume II, contains a mixture of technical reports and notes, as well as a number of reports on European aerial archaeology and specific-site studies in England. A common methodological thread runs through virtually all of these papers: the almost exclusive use of oblique aerial photographs. Of particular interest are a number of technical discussions of the use of obliques for mapping and monitoring sites through optical-mechanical rectification (J. N. Hampton) and sophisticated computer methods (Rog Palmer, Irwin Scollar). Derek Bridson discusses cameras for oblique photography at length. A historical basis for the emphasis on oblique imagery, of course, is that most early aerial photographs taken over archaeological sites were exposed using hand-held cameras from an airplane's cockpit, and there must be an enormous archive of such photographs which must be referred to today for