051371

10259-1-X

Reprinted From

PROCEEDINGS of the SEVENTH INTERNATIONAL SYMPOSIUM on REMOTE SENSING OF ENVIRONMENT

17-21 May 1971

Sponsored by

Center for Remote Sensing Information and Analysis
Willow Run Laboratories, Institute of Science and Technology
The University of Michigan

Water Quality Office
Environmental Protection Agency

Office of Space Science and Applications
National Aeronautics and Space Administration

Federal Highway Administration
U. S. Department of Transportation

U. S. Geological Survey
U. S. Department of Interior

Air Force Cambridge Research Laboratories
Air Force Systems Command
U. S. Air Force

Agricultural Research Service
U. S. Department of Agriculture

Infrared and Optics Laboratory
Willow Run Laboratories
INSTITUTE OF SCIENCE AND TECHNOLOGY
THE UNIVERSITY OF MICHIGAN
Ann Arbor, Michigan

DETECTION OF SOUTHERN CORN LEAF BLIGHT BY REMOTE SENSING TECHNIQUES*

M. E. Bauer, P. H. Swain, R. P. Mroczynski,

P. E. Anuta and R. B. MacDonald

Laboratory for Applications of Remote Sensing
Purdue University
Lafayette, Indiana

ABSTRACT

Multispectral photographic and scanner data were collected over western Indiana in August and September, 1970, to determine the detectability of southern corn leaf blight (Helminthosporium maydis) by remote sensing. Spectral measurements in the range 0.4 to 14 micrometers were made with an optical-mechanical scanner at altitudes of 3000 to 7000 feet. Color, color infrared, and multiband black and white photography were collected at altitudes from 3000 to 60,000 feet.

The principal test site for the study was a north-south flightline running the length of Indiana, with six 1 x 10-mile areas in which ground truth information was collected. Ground truth consisted of ratings for each corn field with respect to degree of disease infection. Six levels of infection based on the amount of leaf damage were identified in the fields. Symptoms of the disease are the appearance of brown lesions on the lower leaves; the lesions grow in size and spread to upper leaves until the entire plant is prematurely killed.

Three levels of infection were detected with color infrared photography by standard photo-interpretive techniques. Up to five levels of infection were distinguished by applying automatic pattern recognition techniques to the multispectral scanner data. The results illustrate the potential of remote sensing techniques in the detection of crop diseases.

1. INTRODUCTION

During August 1970, when southern corn leaf blight was invading many of Indiana's corn fields, measurements were made with airborne sensors to determine the feasibility of detecting the disease using remote sensing techniques. The specific objective of the study was to determine the detectability of the various degrees of corn leaf blight infection. The remote sensing techniques used were:

(1) standard photo-interpretive techniques applied to various forms of aerial photography;
(2) automatic pattern recognition techniques applied to digitized multiband aerial photography; and
(3) automatic pattern recognition techniques applied to multispectral scanner data.

The widespread presence in 1970 of southern corn leaf blight offered an opportunity to conduct research on the use of remote sensing techniques for the detection and mapping of crop diseases. The technology and methods developed

* This work was supported by the National Aeronautics and Space Administration Grant Number NGL15-005-112.

for the detection of this blight can be applied to crop diseases or problems occurring in the future. Although southern corn leaf blight is not expected to be a serious problem beyond 1971, it is representative of many disease problems. Examples of diseases which have caused serious losses are almost too numerous to mention; familiar examples include the leaf and stem rusts of the small grains, maize dwarf mozaic, and potato late blight.

The detection and mapping of crop disease outbreaks is an important agricultural application of remote sensing. Surveys conducted over large geographic areas using remote sensing techniques could provide early and comprehensive information on the extent of the disease to agricultural producers, commodity markets, agricultural industries, scientists and government agencies. Complete information on the location and severity of disease infection would be a valuable aid in resource management.

2. SOUTHERN CORN LEAF BLIGHT - NATURE AND EFFECTS

A new race of a previously minor disease of corn, southern leaf blight (Helminthosporium maydis), spread across the South and the Corn Belt during 1970 causing widespread damage. Nationally, the size of the corn crop was 15 percent below the initial July forecast of 4.820 billion bushels. Indiana's corn crop loss from southern leaf blight was 95 million bushels, or about 20 percent of the original estimated production [1]. In individual fields losses were much greater. In 1970 the disease first appeared in southern Florida. From there it spread to Alabama and Mississippi. The disease then fanned out in a northerly direction, and week by week its progress was plotted as it approached the Corn Belt. The disease is a prolific producer of spores which can be borne by the wind. This accounts for the rapid spread from the South to the Corn Belt during the past season. The build-up and severity of the disease is affected by weather conditions; warm temperatures (80° F or above) and humid weather (rains, dews, fogs) favor the development of the disease.

The new "T" race of southern corn leaf blight is highly virulent to corn containing "Texas male-sterile" cytoplasm (a characteristic that eliminates the need for detasseling in hybrid seed production). Eighty-five percent of the seed planted in 1970 contained this characteristic. The first symptoms of the disease are the appearance of small, brown lesions, usually on the lower leaves. The lesions are spindle-shaped and range in size from minute specks up to 1/2 x 1-inch. Several spots may unite to form large areas of dead leaf tissue. Eventually, more lesions are produced from successive infections on the upper leaves. With favorable conditions for the disease, the entire corn plant may be prematurely killed within two weeks after the initial infection.

Six stages of southern corn leaf blight infection based on the amount of leaf damage can be described [2]:

(0) None - no lesions present;
(1) Slight - a few, scattered lesions appearing mostly on the lower leaves, with less than 10 percent of the surfaces of lower leaves affected;
(2) Mild - many lesions appearing on the lower leaves and a few scattered lesions on the upper leaves above the ear; 10 to 30 percent of the lower leaf area and less than 10 percent of the upper leaf area is affected;
(3) Moderate - large areas of the lower leaves are non-functional with scattered lesions on leaves above the ear; 30 to 60 percent of the lower and 10 to 30 percent of the upper leaf surfaces affected;
(4) Severe - lower leaves mostly killed and the upper leaves beginning to die; 60 to 90 percent of lower and 30 to 60 percent of upper leaf surfaces affected;
(5) Very severe - nearly all leaves are non-functional; more than 90 percent of total leaf surface affected.

If considerable amounts of leaf area are killed, the vigor and yield of the plant is reduced and the grain is chaffy and light. When leaves are blighted or killed, the photosynthesis processes for synthesizing carbohydrates are reduced or stopped. The earlier leaf blight appears in the plant's life cycle, the more it reduces yields. If the disease is well-established before or shortly after silking, yields are generally reduced 30 percent or more. If only the lower leaves are severely damaged after the milk stage is reached, yields are reduced less. Yields are also reduced by ear and stalk rots caused by Helminthosporium maydis.

3. EXPERIMENT DESCRIPTION

Test Site and Aerial Data Collected. A flightline over western Indiana following highways U.S. 421, Ind. 43, U.S. 231, and Ind. 57 was established as an experimental test site. The flightline proceeded in a north-south direction from near Michigan City in northern Indiana to near Evansville at the southern end of the state (Figure 1). Color, color infrared and multiband black and white photography were collected over six intensive study areas within the flightline (each eight to twelve miles long) and also over three Purdue flightlines in Tippecanoe County (each 24 miles long) [3]. See Table I.

Ground Data. Ground truth information describing the condition of the corn fields was collected by staff members of the Purdue University Cooperative Extension Service and Agriculture Experiment Station following each of the multispectral scanner flights. Each of the corn fields visited was rated for the amount of leaf damage from southern leaf blight, degree of ear rot and stalk rot present, and stage of maturity of the crop. Additional information was obtained on the percent yield loss from leaf blight and other factors such as drought damage which may have caused premature senescence of the crop.

4. PHOTO-INTERPRETATION RESULTS

The objectives of the photo-interpretation portion of this study were to determine the capability for identifying the corn fields and then classifying these fields into meaningful blight severity groups. Interpretation was from 1/60,000 scale color infrared transparencies collected August 26 by the NASA RB-57F aircraft. A Zeiss RMK camera with a 12-inch focal length lens was used; Kodak Aerochrome infrared type 2443 film was exposed through a Wratten 15 filter.

Intensive Study Area D (Figure 1) was judged to be representative of the data from much of the flightline and was used for developing the interpretive materials. A nine-class photographic key and dichotomous supplement were developed for the interpretation task. The classes defined by the key were:

(1) Woodlots
(2) Pasture or hay crops
(3) Bare soil
(4) Diverted acres (two classes)
(5) Soybeans
(6) Corn A - blight severity class 1 or 2
(7) Corn B - blight severity class 3
(8) Corn C - blight severity class 4
(9) Corn D - blight severity class 5

In the development of the photographic key the interpretive elements of tone and texture (row structure) were emphasized. The elements of size, shape, shadow, and surroundings were of little use in identifying the cover types. The examples used in the photographic key were considered representative of their particular class. However, there was sufficient variation in the appearance of the corn fields to dictate that the key be used only as a guide, utilizing the four corn classes as points on a scale of intensity. Therefore, the decision of the interpreter was a qualitative judgement based on the key and the appearance of the fields on a particular frame. The interpreter used his judgement in classifying the fields falling between the classes defined by the key. The photographic key was used alone after minimal practice. The dichotomous key was supplementary by nature and required more experience to be used alone effectively.

All results shown were obtained with 10X magnification. Magnifications of up to 30X were obtained with a Bausch and Lomb Zoom Macroscope. Generally, patterns obvious at greater magnification were also discernable at 10X magnification.

To carry out the project objectives, the keys were tested on the frames containing the intensive study areas. The test procedure consisted of outlining areas where the ground truth had been collected and then applying the photo-interpretation principles. Little difference was found in the accuracy of identification of the corn fields among the six test areas (Table II), although there was some variation from area to area in the accuracy of placing the fields into the correct leaf blight severity class. Factors other than leaf blight (such as stage of maturity) may have contributed to these differences.

The first color and color infrared imagery collected (at 3000 feet) indicated that three categories of blight-infected corn fields could be distinguished: (1) healthy corn with little or no infection, (2) moderately infected corn where primarily the lower leaves were becoming brown, and (3) severely infected corn in which most of the leaf tissue had been killed. Subsequent analysis of the photography collected at higher altitudes (up to 60,000 feet) also showed that at least three levels of infection could be accurately distinguished (Table III).

Incorrect classification of the corn fields was primarily into adjacent severity classes (Table III). This was not surprising since the ground truth data was based only on the amount of leaf damage and plant maturity stage. Undoubtedly, there were many factors other than southern leaf blight influencing the spectral response of fields (eg., plant population, row width, plant height, leaf area, available soil moisture, and fertility). Also, only one overall rating per field was made even though in some cases the field was not uniform.

There were no fields completely free of southern leaf blight lesions (class 0); therefore, it was not possible to determine if separation of no leaf blight from the earliest stages would be possible. It is expected that it would have been very difficult if not impossible to make this discrimination since only a small part of the lower leaves are affected at stages 1 and 2 and these two classes were inseparable. The lower leaves have little effect on the total radiance of plants when measured from directly overhead. Under the conditions of late August and early September it was not possible to determine if severely blighted fields could be separated from those which had senesced due to normal maturity.

The color infrared imagery was found to be considerably more useful than color film with respect to accurate identification of blight classes. This may be due to the greater haze penetration of color IR films, which improves image contrast and quality. Haze penetration is an important factor in late-season aerial photography in the Corn Belt region.

5. ANALYSIS OF DIGITIZED AERIAL PHOTOGRAPHY

Digitized aerial photography of the corn blight test sites was analyzed using a multispectral pattern recognition system.* The photography was obtained in two forms: black and white multiband, and color infrared. The black and white multiband photography was obtained from three 70 mm cameras having film filter combinations which sensed approximately the .48-.61, .59-.71, and .68-.89 micrometer bands. The color infrared film senses approximately the same bands.

Digitization of the multiband black and white photography was done with a rotating-drum microdensitometer which measured the film density at a .001-inch resolution and digitized the measurements to eight-bit precision. The .001-inch resolution corresponded to a ground resolution of approximately 20 feet. The density measurements were initially stored as separate data sets on magnetic tape since the 3 transparencies were scanned in separate steps. The data were overlayed using a digital computer so that the measurements in the three bands could be stored in geometric coincidence.

The three bands sensed by the color infrared film are represented by the density of three colored dye layers in the developed transparency. Color separation must be performed either prior to or during scanning to obtain separate measurements of the exposure in the three bands. Therefore, the color infrared

---

* All automatic data processing was performed using LARSYS, a computer software system developed at LARS/Purdue for remote sensing applications [4], [5].

transparency was scanned by a vidicon system using red, green, and blue filters to produce three digital representations of the exposures of the three dye layers. Again the data were digitally registered to produce a coincident three-channel data record of the same form as the multiband black and white data (the scanning resolution was also approximately the same).

A comparison was made of classification results using both types of film data. The corn, soybean, etc., fields used in the aircraft scanner data analysis (see below) were located in gray-scale printouts of the digitized film data and the multispectral classification procedure was applied. The comparison was made using only the red and infrared bands because an electronic problem in the color separation scanner caused the loss of the blue dye measurement representing green wavelengths. Another problem in the digitization arose because the two sets of imagery were scanned at different orientations (the color data was rotated 30 degrees with respect to the black and white data). Since the training field boundaries had to be rectangular and orthogonal to the direction of scan, identical boundaries could not be used for both sets of data.

The comparison of classification accuracies for the red and infrared bands is shown in Table IV. Although the film scanning problems made an exact comparison impossible, the generally poorer result for the color film tends to reinforce the notion that the overlap of the bands and focus problems may result in less spectrometric fidelity for color infrared than for optimally exposed multiband black and white film.

The three-band black and white multispectral film results were also compared with the aircraft scanner data results (Table V). For this comparison, the four-band aircraft scanner data results were used because they represented about the best that could be obtained from the scanner data. The three-band film data results were the best achieved with photography. The film data results were generally poorer than the scanner results except for identification of soybeans and pasture. Photographic discrimination of the five blight levels was fair but not competitive with the scanner discrimination. If only corn as a class is considered, the film data performance was the same as the scanner data performance.

6. MULTISPECTRAL SCANNER DATA ANALYSIS

Analysis of the multispectral scanner data collected August 24 was limited because of the marginal quality of the data. Cloud cover and low illumination characterized practically all of the six intensive study areas. One exception was a portion of area D which contained a reasonable number of fields not obscured by cloud cover. The corn fields in the area were divided into classes according to blight severity level and into subclasses based on spectral differences. A total of fourteen corn subclasses were defined. Attempts to correlate such factors as crop maturity stage, row direction, and view angle with the subclasses were inconclusive. The feature selection processor, using divergence as a measure of statistical separability, was used to determine the best 2, 3, 4, 5, and 11 channels out of the 12 available visible and reflective infrared channels. The results indicated that as few as three channels could be used to obtain adequate separability of the blight levels.

A classification of the training fields was performed using the .44-.46, .50-.52, .55-.58, and .80-1.00 micrometer bands. These bands were selected in order to maximize the minimum divergence between the different blight severity levels. Performance for training fields was 78.0 percent correct recognition, which increased to 87.1 percent when 11 of the 12 visible and reflective infrared channels were used. A short segment of area D was then selected for overall classification. Six "other" classes consisting of pasture, wheat stubble, trees, and three soybean classes were defined. A classification using 12 channels over the range 0.4 to 1.0 micrometers produced results which were qualitatively very satisfactory (Figure 2). The classification map indicated that most corn fields were classified accurately. The majority of errors in classification resulted from "other" cover types being incorrectly classified as corn. There was good agreement between the computer classification and the ground truth ratings for southern corn leaf blight.

The analysis was then extended to include a total of 17 channels of data including three middle infrared channels over the range 1.0-2.5 micrometers and two thermal infrared channels over the range 4.5-14.0 micrometers. The training fields were edited to lie inside the 40-degree field of view of the thermal channels (the other channels have an 80-degree field of view) so that all subsequent results would be compatible. Eleven classes were defined representing blight severity levels 1 through 5. Four "other" categories were also defined (pasture, stubble, and two soybean classes). The most accurate classification of the blight severity levels (78.7 percent correct recognition) was obtained using the .44-.46, .58-.62, 1.0-1.4 and 1.5-1.8 micrometer channels. The reflective infrared channels definitely aided in classification, both in discriminating corn from other ground cover types and in differentiating between blight severity levels. However, in this particular analysis the thermal infrared channels were found to be of no assistance in either of these respects. The latter result was surprising since the thermal characteristics of healthy green vegetation were expected to be distinctly different from the thermal characteristics of dried, diseased vegetation. It may be that the late afternoon hour at which the data were collected affected the observed response substantially. Thermal channels were found to be beneficial in later analyses of other data.

The corn blight data collected September 5, over Intensive Study Area D included data collected from altitudes of 3000 and 7000 feet. By September 5, the condition of the corn fields had deteriorated considerably from the August 24 flight. Clear weather prevailed while these data were collected. The optimum set of four spectral bands for classification selected from the 13 channels (0.40-2.60 micrometers) collected at 3000 feet were 0.40-0.44, 0.62-0.66, 1.00-1.40 and 1.50-1.80 micrometers. Spectral bands of 0.55-0.58, 1.00-1.40, 1.50-1.80 and 8.0-14.0 micrometers were chosen when the thermal channels were considered. The results of these classifications are shown in Tables VI and VII. There was some improvement in accuracy of classification of the blight severity levels when a thermal channel (8.0 to 14.0 micrometers) was included in place of a lower wavelength channel; however, the accuracy for separating other cover types was reduced.

In the analysis of the data collected at 7000 feet, the spectral bands .58-.62, .66-.72, 1.0-1.4, and 1.5-1.8 micrometers were selected as the best four channels for classification. The recognition of corn fields compared favorably with that obtained for the 3000-foot data; however, separation of the corn into blight severity classes was not as accurate (55.5 percent correct).

The scanner data from Flightline 24 in Tippecanoe County were also analyzed. The classification results (Table VIII) were quite good. This flightline was 24 miles long; the ground truth was collected from only about 20 percent of the fields scattered over the flightline. This contrasts with the intensive study areas which were shorter and for which ground truth was collected from nearly all fields. The spectral bands used for this classification were .40-.44, .55-.58, 1.00-1.40 and 1.50-1.80 micrometers.

7. SUMMARY AND CONCLUSIONS

Analysis of multispectral photography and scanner data showed that southern corn leaf blight was detectable in late August and early September from altitudes of 3000 to 60,000 feet. In color infrared imagery, three degrees of severity (slight, moderate, and severe) were identified with an average accuracy of 80 percent. The color infrared photography was found to be a better medium for this interpretation task than regular color photography. Separability of the various blight classes was enhanced in the color infrared.

Portions of the aerial photography were digitized and analyzed using pattern recognition. Somewhat greater accuracy was obtained from the three-band black and white films than from color infrared film. However, the classification results were not as accurate as those obtained from the analysis of the scanner data.

In the multispectral scanner data as many as five severity levels of southern leaf blight ranging from mild to severe were detected and classified. Overall performance for classification of severity in test fields averaged 75 percent. Much of the corn misclassification was into adjacent severity levels, which was reasonable since the ground truth accounted for only one level within a field whereas both the photography and scanner imagery confirmed that variations existed within many fields. In all cases, the near infrared channels (0.8 to 2.6

micrometers) were valuable in achieving accurate classification of the severity levels. In most instances use of the thermal infrared channels added to this accuracy.

In conclusion, analysis of representative portions of the photographic and scanner data collected in 1970 for study of the detectability of southern corn leaf blight have shown that this disease can be detected by remote sensors, and further, that several degrees of blight infection can be accurately classified. The results illustrate the potential application of remote sensing techniques to the detection of crop diseases.

REFERENCES

1. "Crop Production," U.S. Dept. of Agriculture, Statistical Reporting Service, CrPr 2-2 (12-70), 1970.

2. Ullstrup, A. J., "Corn Diseases in the United States and Their Control," U.S. Dept. of Agriculture Handbook No. 199, 1961.

3. "Southern Corn Leaf Blight: Status Report No. 2," LARS Information Note 091170, Laboratory for Applications of Remote Sensing, Purdue University, Lafayette, Indiana, September 11, 1970.

4. "Remote Multispectral Sensing in Agriculture," Report of the Laboratory for Agricultural Remote Sensing, Vol. 3, Purdue University Agricultural Experiment Station, Research Bulletin No. 844, Lafayette, Indiana, 1968.

5. "Remote Multispectral Sensing in Agriculture," Report of the Laboratory for Agricultural Remote Sensing, Vol. 4, Purdue University Agricultural Experiment Station, Research Bulletin No. 873, Lafayette, Indiana, 1970.

TABLE I. AERIAL DATA COLLECTED FOR 1970 SOUTHERN CORN LEAF BLIGHT DETECTION EXPERIMENT.

Date	Aircraft	Area and Altitude	Data
Aug. 19,21,24 and Sept. 11	Purdue Univ. Beechcraft	Tippecanoe Co. and six intensive study areas (3000'-10,000')	35 and 70mm color and color infrared photography
Aug. 26 and Sept. 9	NASA RB-57F	N/S flightline (60,000' and 50,000')	9 inch color and color infrared and 70mm multiband photography
Aug. 24, and Sept. 5 and 11	Univ. of Michigan C-47	Six intensive study areas and FL 21,23, and 24 (3000'-7000')	Multispectral scanner; black and white, color and color infrared photography

N/S - north/south; FL - flightlines

TABLE II. IDENTIFICATION BY PHOTO-INTERPRETATION OF CORN FIELDS AND SOUTHERN CORN LEAF BLIGHT SEVERITY IN SIX AREAS IN WESTERN INDIANA.

Area	Number of Fields	Percent of corn fields correctly identified as corn	Percent of correctly identified corn fields classified into correct leaf blight class
A	25	88	64
B	22	83	91
C	34	96	76
D	26	85	57
E	29	94	76
F	27	100	78
Mean		91	74

TABLE III. RECOGNITION OF SOUTHERN CORN LEAF BLIGHT SEVERITY CLASSES FROM 1/60,000 SCALE COLOR INFRARED FILM USING 10X MAGNIFICATION.

Class	Number of Fields	Number of Fields Classified As					Percent Correct Classification
		1-2	3	4	5	Other	
Severity 1-2	68	50	15	3			73
Severity 3	54	6	39	7	1	1	72
Severity 4	33		6	25	1	1	76
Severity 5	8			1	6	1	75
Other	159	1	8	2		148	93

Overall accuracy of blight severity classification = 73.6%.

TABLE IV. COMPARISON OF CLASSIFICATION RESULTS FOR DIGITIZED MULTIBAND BLACK AND WHITE AND COLOR INFRARED FILM (INTENSIVE STUDY AREA D, AUGUST 26, 1970).

Class	Black and White: No. Samples	Black and White: Percent Correctly Classified	Color Infrared: No. Samples	Color Infrared: Percent Correctly Classified
Severity 1	2279	52	5933	37
Severity 2	517	74	135	80
Severity 3	1849	31	2945	61
Severity 4	1530	75	3509	50
Severity 5	679	58	*	*
All corn	6854	93	14,522	88
Soybeans	1735	74	4062	80
Stubble	467	30	759	21
Hay or pasture	153	99	646	97
Trees	282	79	792	32

* No data for corn blight level 5 existed in the area covered by the color film.

TABLE V. COMPARISON OF TRAINING FIELD CLASSIFICATION RESULTS FOR SCANNER DATA AND DIGITIZED MULTIBAND BLACK AND WHITE FILM (INTENSIVE STUDY AREA D).

Class	Scanner[1]: No. Samples	Scanner[1]: Percent Correctly Classified	Black and White Films[2]: No. Samples	Black and White Films[2]: Percent Correctly Classified
Severity 1	352	76	2519	58
Severity 2	136	90	517	77
Severity 3	304	67	2502	45
Severity 4	290	99	1530	78
Severity 5	64	95	679	87
All Corn	1146	95	7747	95
Soybeans	1218	79	1735	92
Stubble	81	63	467	47
Hay or pasture	187	97	153	100
Trees	195	92	273	91

[1]Spectral bands .44-.46, .58-.62, 1.0-1.4, and 1.5-1.8 micrometers.

[2]Green, red, and reflective infrared bands.

TABLE VI. CLASSIFICATION RESULTS USING VISIBLE AND NEAR INFRARED CHANNELS (INTENSIVE STUDY AREA D, SEPTEMBER 5, 1970, 3000 FEET).

Class	Number of Samples	Number of Samples Classified As: 2	3	4	Other	Threshold*	Percent Correct Classification
Severity 2	603	546	25	19	11	2	90.5
Severity 3	866	54	703	67	41	1	81.2
Severity 4	1348	201	75	1004	67	1	74.5
Other	1743	37	223	56	1392	34	79.9
	4559						

Overall Performance = 80.0%

* No classification decision made.

TABLE VII. CLASSIFICATION RESULTS USING VISIBLE, NEAR INFRARED AND THERMAL INFRARED CHANNELS (INTENSIVE STUDY AREA D, SEPTEMBER 5, 1970, 3000 FEET).

Class	Number of Samples	Number of Samples Classified As: 2	3	4	Other	Threshold*	Percent Correct Classification
Severity 2	603	566	7	20	5	5	93.9
Severity 3	866	12	688	111	35	20	79.4
Severity 4	1348	117	37	1146	47	1	85.0
Other	1743	12	180	188	1230	132	70.6
	4559						

Overall Performance = 79.6%

* No classification decision made.

TABLE VIII. CLASSIFICATION RESULTS FOR FLIGHTLINE 24, SEPTEMBER 5, 1970 AT 3000 FEET.

Class	Number of Samples	Number of Samples Classified As: 1	2	3	4	Other	Threshold*	Percent Correct Classification
Severity 1	912	571	216	45	0	79	1	62.6
Severity 2	1545	12	1169	145	0	217	2	75.6
Severity 3	5222	104	626	3315	419	751	7	77.9
Severity 4	1034	0	27	261	677	69	0	83.5
Other	20517	176	765	486	12	18210	868	88.7
	29230							

Overall Performance = 81.9%

* No classification decision made.

FIGURE 1. AUGUST AND SEPTEMBER, 1970 FLIGHTLINE. Cross-hatched regions are intensive study areas.

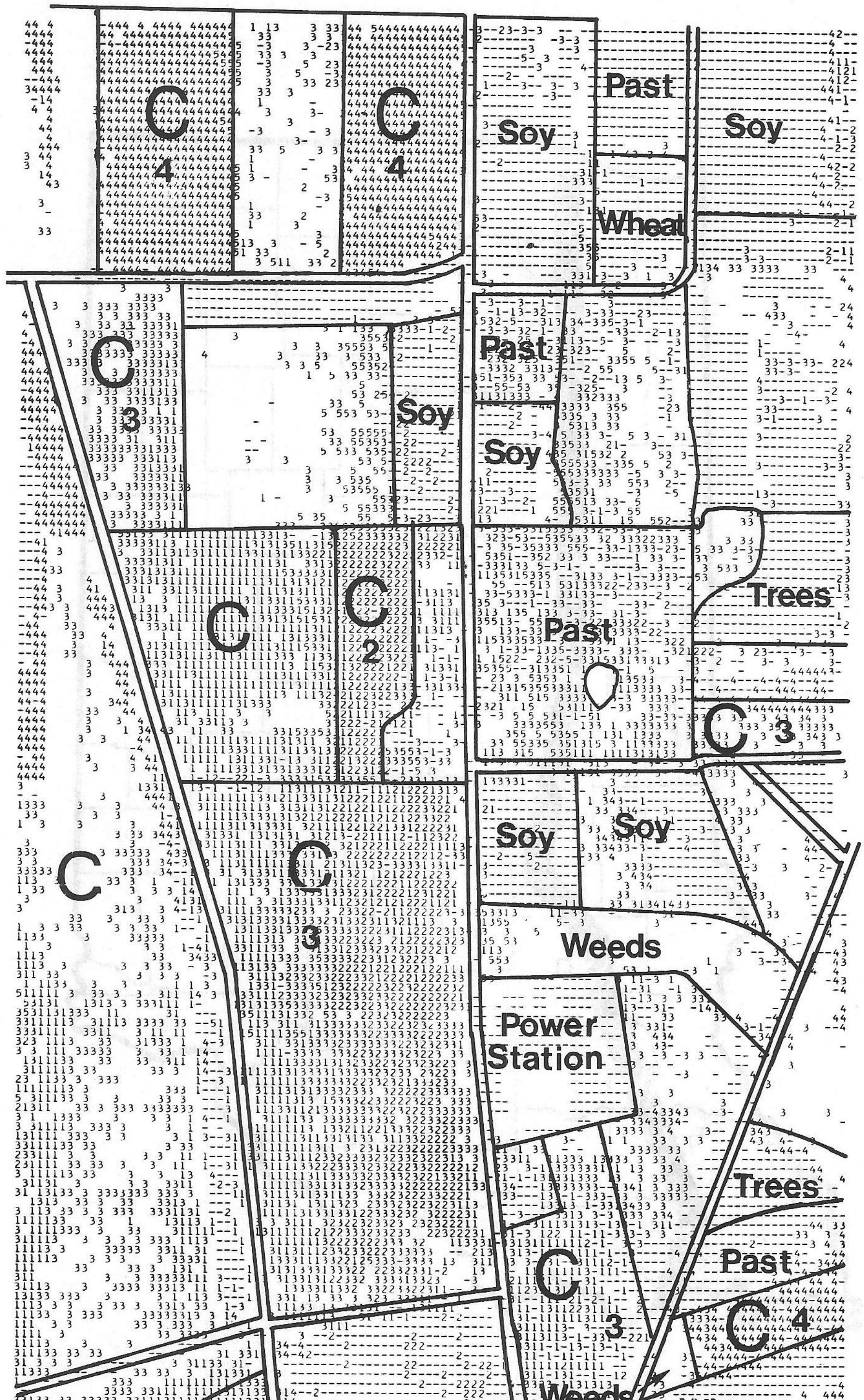

FIGURE 2. COMPUTER CLASSIFICATION OF FIVE CORN LEAF BLIGHT SEVERITY LEVELS OVER AREA D, AUGUST 24, 1970. The large letters and numbers represent the ground rating of the degree of leaf damage from blight. Small characters represent computer classification: Numerals for corn blight severity, hyphen for "other" ground cover, blank for "no classification decision made".