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DETECTION OF SOUTHERN CORN LEAF BLIGHT BY REMOTE SENSING

Status Report No. 3

by

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I. Introduction

Analysis is continuing of the multispectral scanner and photographic data collected during August and September for study of the detectability of southern corn leaf blight by remote sensing. The reader is referred to LARS Information Notes Numbers 083170 and 091170 for background information on the type of data collected and early results of the analysis. This report includes further results of the study.

II. Analysis of Multispectral Scanner Data - August 24 Flight

The data collected on August 24, 1970 consisted of two passes over the intensive study areas. Due to marginal weather conditions, i.e. considerable cloud cover, the data collected over the first pass (north to south) was unusable. Cloud cover plus irregular ground geometry caused the two southernmost segments of the north bound pass to be ignored as well. Based on considerations related to the ground truth, i.e. an interesting distribution of blight severity levels, it was decided to begin the analysis with intensive study segment A, the northernmost of the intensive study areas.

The study was begun by making a collage tape consisting of those cornfields in area A for which ground truth had been collected. The clustering program was applied to this tape to determine whether the spectral differences in these fields were due to corn blight effects. The results were negative. Based on an arbitrary selection of channels 2, 4, 6, 8, 10 and 12, all "visual" channels, the clustering results could not be said to differentiate between different blight severity levels. A similar experiment was run for areas B and C, also with discouraging results.

The ground truth fields for area A were then divided into classes according to blight severity level. The histograms of the resulting classes were clearly unimodal, so the statistics were input to the divergence processor to determine the separability of the severity classes. It was found that the classes were non-separable, even when as many as 11 channels were used. The minimum interclass divergence for the 11 channel case was only 1. Furthermore, overlaying and analyzing the thermal IR channels in conjunction with the visual channels yielded no significant improvement. Therefore a classification of the data was not attempted. It is speculated that the overall homogeniety of the data was primarily due to the low light level at the time that the data was collected (6:20 p.m. for area A).

Attention was then shifted to area D on the northbound pass (designated D2). This part of the data contained a reasonable number of fields with ground truth which were not obscured by cloud cover. The distribution of the corn fields between blight severity levels was also quite satisfactory for study purposes.

In this case, clustering was not investigated, mainly because of the discouraging results obtained using clustering in area A. (In retrospect, however, it may have been worthwhile to have considered clustering for area D). In this case the fields for which ground truth data was available were divided into classes according to blight severity level. The classes proved to be multimodal and so were divided into subclasses on the basis of comparison of histograms of the fields. The result was a total of 15 training classes distributed among five blight severity levels. (Level 0 was not represented in this area). It was later determined that one of the subclasses associated with severity level 1 consisted of very mature corn fields, and this subclass was indistinguishable from the subclass representing very severe corn blight. For this reason the former subclass was omitted from the analysis. Thus a total of 14 training classes representing blighted corn remained. An attempt was made to correlate "natural" factors (maturity, view angle, row direction, etc.) with the subclasses but the results were inconclusive.

The divergence processor was used to determine the best 2, 3, 4, 5, and 11 channels out of the 12 available visible channels of data. The results indicated that as few as 3 channels could be used to obtain adequate separability between blight levels (0 weight was attached to all subclass combinations within any given blight severity level). See Table 1.

A classification of the training fields was then performed using channels 2, 5, 7, and 12. These channels were selected in order to maximize the minimum divergence between subclasses in different blight severity levels. The resulting classification accuracy was 74.9%. By ignoring errors between subclasses within a severity level the overall performance was increased to 78.0% correct recognition. A classification was then run using 11 of the 12 visual channels. Channel 4 was omitted. In this case, overall performance was 84.8% correct recognition or, ignoring errors between subclasses within a severity level, 87.1% correct recognition.

A short segment of area D was then selected for overall classification. (The previous classifications had consisted of training fields only). Six "other" classes were defined: pasture, wheat, trees, and three classes of soybeans. This produced a total of 20 classes. The area considered consisted of lines 1925 through 2439 of Run No. 70008300 (area D, northbound pass). The divergence processor indicated reasonable separability between all pairs of classes involved. A classification using all 12 visual channels produced results which were qualitatively very satisfactory (these results were included in Corn Blight Status Report No. 2, LARS Information Note 091170). Quantitative tabular results were not obtained for this classification. However, an interesting feature of these results was the discovery that up to a 99% threshold level, i.e. thresholding out of 99% of the samples, theoretically, produced hardly any actual thresholding. (One wonders if the approximation used to compute the chi-square value for thresholding in LARSYSAA is really performing correctly). The classification map indicates that most corn fields were classified to a very high degree of accuracy. The majority of errors in the classification resulted from "other" cover types being incorrectly classified as corn. The greatest offenders in this respect turned out to be pastures. Normally, one would have hoped that these errors would be removed by thresholding, but as noted above, thresholding had very little effect on the classification.

The analysis was then extended to include a total of seventeen channels of data including three near IR channels over the range 1.0-2.5 micrometers and two thermal IR channels over the range 4.5-14.0 micrometers which had been overlaid on the "visible" data. Since the field of view of the thermal channels is only 40°, the training fields were edited to lie inside the 40° field of view so that all subsequent results would be comparable. Based on field and class histograms, eleven classes were derived representing blight severity levels 1 through 5. Four "other" categories were also defined (pasture, wheat, stubble, and two soybean classes).

The divergence processor was used to select 1) the best four channels out of 12 visible channels, 2) the best four channels out of 12 visible plus 3 near IR channels, and 3) the best four channels out of all 17 available channels. The results of using the selected channels to classify the training fields are shown in Tables 2 and 3. The near IR channels definitely aid in classification, both in discriminating corn from other ground cover types and in differentiating between blight severity levels. However, the thermal IR channels did not assist in either of these respects. Given all 17 channels to choose from, the divergence processor did not select either thermal IR channel. And when the best 4-feature combination containing at least one thermal IR channel was used for classification, the classification accuracy degraded slightly.

The latter result was somewhat surprising since the thermal characteristics of relatively healthy green vegetation are surely significantly 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. Further investigation along these lines is required.

Summarizing, then, the analysis of the August 24, 1970 mission data was somewhat limited due primarily to problems arising out of marginal weather conditions at the time of the mission. The results which have been obtained appear to indicate that the Southern Corn Leaf Blight can be detected in multispectral scanner data. Preliminary indications are that at least five levels of blight severity are discriminable at this stage of the growing season, although severely blighted corn may be difficult to discriminate from rather mature corn. Data in the .4-1.0 micrometer region are reasonably effective in detecting blighted corn; additional aid can be gotten from the near IR (1.0-2.5 micrometers) region. It is not yet clear whether the thermal IR data (4.5-14 micrometers) is of value.

Table 1. Results from Divergence

Processor for 2,3,4,5, and 11 channels.

No. of channels	"Best" channels	D(AVE)*	DIJ(MIN)
2	5,12	78/16	4
3	2,10,12	145/17	7
4	2,5,7,12	-/17	8
5	2,5,7,10,12	193/17	10
11	1-3,5-12	259/17	13

* Given as value obtained with no MAX/value obtained with MAX=20.
- Value not determined

Table 2. Comparison of results using visible and IR data

	Channels Selected	D(AVE)	DIJ(MIN)	%Correct Recognition
Best 4 of 12 visible	2,8,10,12	21	8	70.3
Best 4 of 15 visible and near IR	2,8,13,14	21	11	78.7
Best 4 of 17 available	2,8,13,14	21	11	78.7
Best 4 of 17 with at least one thermal	8,13,14,17*	21	9	77.9

* Ranked 30th among all combinations of 4.

Table 3. Effect of channels on blight severity discrimination alone

Channels Selected	Overall Error (%)	"Other" Errors (%)	Net Blight Error (%)
2,8,10,12	29.7	13.9	15.8
2,8,13,14	21.3	11.0	10.3
8,13,14,17	22.1	11.9	10.2

III. Analysis of Multispectral Scanner Data - September 5 Flight

An analysis of segment D3 of the September 5, 1970 data mission for corn blight was made in the following manner: Data from 3000 foot altitudes was displayed on grey scales in the .62-.66 and .8-1.0 micrometer wavelength bands. Ground truth information on corn blight severity levels and corn crop maturity was added to the listings. Corn fields with complete information which were also free from cloud shadows were designated as training areas. A square area from the center of each of these fields was used as input for a clustering algorithm which automatically divided the data into spectrally different classes. The clustered output was examined visually to determine which clustered classes corresponded to blight severity and maturity levels. It was found that severity and maturity levels occurred in several clustered classes with only broad and indistinct patterns discernible. Three levels of severity were selected and each level was subdivided into three subclasses in an attempt to provide training fields based on blight severity levels.

Other ground cover training fields were selected manually and combined with the corn blight training fields. These areas were processed by LARSYSAA and a classification was produced of the clear areas on segment D3. Results of this classification indicated that corn blight severity levels could not be accurately identified on this data. This may be due to the high maturity level which might produce similar specular responses in the scanner data. There were also errors in classification between corn and soybean fields which were in the late stages of maturity.

IV. Analysis of Digitized Photography

Digitization and computer analysis of photography of corn blight infested areas is proceeding along four lines. The film being studied was exposed during a NASA RB-57 flight near Worthington, Indiana on August 26, 1970. Two types of film are being studied: 70mm multiband black and white, and 9" x 9" color infrared. The film is being scanned, digitized and overlayed so that a 3 band data storage tape is created which represents the photograph in digital form. A second corn blight test area is being selected and film processing will begin soon.

The 9" x 9" color infrared photograph is being scanned and digitized in three ways. First, the color IR transparency is being used to make three color separation prints which will then be scanned and digitized on the IBM drum film scanner at the Houston Scientific Center. Secondly, a vidicon film scanner is available at IBM HSC which can scan and color separate blocks of 256 by 350 points in the film transparency. This device is being used to scan blocks in the corn blight test area and the data is being mailed to LARS in card form. The third scan will be performed by the Fairchild Company using their color separation scanner. The color separation prints are being made by NASA Houston at this time for task 1. Task 2, a color separation scan of a block near the top of area D has been scanned by the vidicon and punched cards containing the data are enroute to LARS. Negotiations are in progress with Fairchild for their scanning for task 3.

The fourth film scan task has been completed and overlay of this data is in progress. The green, red, and IR, black and white 70mm films of area D were scanned on the Optronics scanner in the Biological Sciences Department in cooperation with Dr. Michael Rossman. The film was scanned at .001 in resolution so the ground resolution should be about 26 feet which is comparable to the aircraft scanner resolution. A three band data tape from this scan should be ready for analysis by mid-November.

V. Photo-interpretation

The objectives of the photo-interpretation study are to identify corn fields and classify these fields into a meaningful blight severity group. The primary data used in this study has been the 1:60,000 Ziess color infrared photography collected August 24, 1970 by a RB-57F aircraft.

Other photography pertinent to this study includes large (1:3,000) to small (1:360,000) scale photography collected from various aircraft between August 14 and September 11, 1970.

One set of data that could have been of particular interest to LARS researchers was collected by Rome Air Development Center. This data consisted of black and white, color and color IR films at a 1:20,000 scale variously filtered to yield nine 70mm images. The first overflight, August 26, 1970, yielded a set of uninterpretable, poorly exposed imagery and was disregarded. The data collected September 11, 1970 was of marginal value since the aircraft flew approximately 1 1/2 miles to the side of the flight line. It is unfortunate that neither set of 9 lense imagery was useful. LARS researchers had hoped that by varied filtration of the different film types that blighted areas might be enhanced.

70mm color and color infrared photography were received only from the August 24 University of Michigan overflight. Exposure problems combined with heavy cloud cover made this set of data marginal for interpretation and it cannot be extensively used.

Other data collected by the NASA RB-57F aircraft are the 1:120,000 RC-8 and 1:360,000 Hasselblad photography from the August 24 and September 9 missions. At this time, considering present capabilities and equipment at LARS these data sets are considered to be of a secondary nature due to their small relative scale.

The Ziess photography from the September 9 flight has not yet been extensively interpreted. In some areas it may be difficult to separate the effects of normal maturity from the blight on this time of year.

Keys in the form of charts were developed over area D for the Ziess 1:60,000 scale photography of the August 26 flight. Ground truth collected at the time of the flight and visual appearance of the keys were the basis for the keys. Ground cover defined by the keys consisted of: soybeans, pasture, hay crops, trees, bare soil, and diverted acres. The diverted acres group was considered to be any category not otherwise defined. The corn fields in area D ranged from the dough to ready to harvest maturity stage. Blight levels from mild to very severe (1 to 5) were found.

The crop identity and corn vigor keys developed for area D on the Ziess 1:60,000 scale photography have been tested for two areas in the northern and central parts of the state. The test procedure consisted of finding and identifying two areas where ground truth had been collected. Using the ground truth as a control the identification accuracy for areas B and C were 60 and 99%, respectively. The increased accuracy for area C is due to the use of both large and small scale photography during the interpretation. For both areas only a maximum 10X magnification was utilized.

The classification accuracy of corn blight fields was 65% and 70% for areas B and C, respectively. These figures represent the accuracy of classifying blight in only those corn fields that were correctly identified, i.e.: weighted averages. Although relatively high, improvements could possibly be made by re-selecting training fields that are more representative of blight conditions.

Row structure was found to be an important factor in identification of the corn fields. At 10X magnification, rows are not always apparent on the small scale photography. It can be assumed that magnification of the Ziess photography would improve identification accuracies. The degree of magnification required has not been determined; however, a study is being undertaken to determine the effect of magnification on interpretation accuracy.

A photographic key is being developed to replace existing keys. The chart keys are cumbersome and the descriptions are sometimes inadequate when color is the only interpretative device. Photographic keys, however, make use of the primary interpretation factor, color and are simpler to use.

It should be emphasized that for all the photo-interpretation tests the film being used was collected August 26, 1970 with a Ziess RMK, 12-inch focal length mapping camera yielding a photographic scale of 1:60,000. The film collected during that flight was Ektachrome infrared. The resulting copies received at LARS vary in density and image quality but are suitable for the present research.

APPENDIX

Table A1. Channels and wavelength bands (micrometers) of the August 24 and September 5, 1970 scanner data.

August 24		September 5	
Channel	Wavelength Band	Channel	Wavelength Band
1	.40 - .44	1	.40 - .44
2	.44 - .46	2	.46 - .48
3	.46 - .48	3	.50 - .52
4	.48 - .50	4	.52 - .55
5	.50 - .52	5	.55 - .58
6	.52 - .55	6	.58 - .62
7	.55 - .58	7	.62 - .66
8	.58 - .62	8	.66 - .72
9	.62 - .66	9	.72 - 80
10	.66 - .72	10	.80 - 1.00
11	.72 - .80	11	1.00 - 1.40
12	.80 - 1.0	12	1.50 - 1.80
13	1.0 - 1.4	13	2.00 - 2.60
14	1.5 - 1.8		
15	2.0 - 2.6		
16	4.5 - 5.5		
17	8 . - 14.0		