N73-16064

LARS Print 100272

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The work described in this
report was sponsored by
NASA under Grant No.
NGL 15 - 005 - 112.

RESULTS OF THE 1971 CORN BLIGHT WATCH EXPERIMENT

Robert B. MacDonald, National Aeronautics and Space Administration
Marvin E. Bauer, Purdue University
Richard D. Allen, U. S. Department of Agriculture
Joseph W. Clifton, U. S. Department of Agriculture
Jon D. Erickson, University of Michigan
David A. Landgrebe, Purdue University

1. INTRODUCTION

A serious and unexpected epiphytotic of southern corn leaf blight reduced the nation's corn crop by 15 percent as a new race of this previously minor disease swept through the Southern and Corn Belt states during July and August, 1970. The disease appeared so suddenly and moved with such speed that accurate information on its extent and severity was not compiled until well after the end of the growing season.

Research by the Laboratory for Applications of Remote Sensing (LARS) in 1970 had shown that three stages of blight infection could be accurately classified from small scale color infrared photography and multispectral scanner data. It therefore appeared that remote sensing could provide valuable information on the incidence and severity of blight as it developed in 1971.

Many advancements in remote sensing technology have been made in recent years, but never before had all the components of an information system utilizing remote sensing measurements been assembled in one package. Thus the Corn Blight Watch Experiment was born out of a need to demonstrate and evaluate remote sensing in a real world situation.

USDA and NASA along with LARS, Willow Run Laboratories, and the Cooperative Extension Services (CES) and Agricultural Experiment Stations (AES) of seven Corn Belt states therefore joined forces to conduct an experiment which included all phases of an information system - remotely-sensed measurements, ground observations, a sampling model, data analysis, and an information dissemination network.

The objective of the experiment was to evaluate the use of advanced remote sensing techniques to:

- Detect the development and spread of SCLB during the growing season across the Corn Belt region;
- Assess the extent and severity of blight infection present in the Corn Belt;
- Assess the impact of blight on corn production;
- Estimate the applicability of these techniques to similar situations occurring in the future.

2. THE CORN BLIGHT PROBLEM

Southern corn leaf blight (SCLB) is caused by the fungus *Helminthosporium maydis*. The disease has been known for many years and is widespread in corn-growing tropical areas of the world. Until 1969, SCLB was considered a minor disease in the United States since it seldom caused severe leaf damage or loss in yield. At that time, a new race of H. *maydis* (race T) adapted itself to Texas male-sterile (TMS) cytoplasm corn. Ninety percent of the 1970 crop was the TMS type corn.

The 1970 Corn Blight Epiphytotic - Three factors were responsible for the corn blight epiphytotic of 1970: (1) a susceptible host (in this case Texas male-sterile cytoplasm corn), (2) a virulent pathogen (in this case a new pathogenic race of the fungus H. maydis), and (3) a favorable environment for the pathogen (in many diseases caused by fungi, of which SCLB is one, warm, damp weather is ideal). The absence of any one of these three factors would have prevented the widespread development of SCLB in 1970. The rapid and widespread development of SCLB in 1970 is shown in Figure 1.

Reduction in 1970 corn yields from SCLB was difficult to estimate. However, blight, combined with severe drought conditions in some areas, is estimated to have reduced 1970 corn production about 700 million bushels from the original forecast total of 4.8 billion bushels. The forecast average yield per acre on July 1, 1970 was 83.1 bushels per acre; in December it was estimated that the harvested yield was an average of 71.7 bushels per acre--a reduction of 15 percent. In some states the average yield loss was greater and in many individual farm fields the crop was nearly a total loss.

Symptoms of SCLB are characterized by tan or light-brown spots or lesions that usually appear first on the lower leaves (Figure 2). Under suitable conditions wind or splashing rain carries spores to upper leaves producing secondary infections. Lesions are oblong and about 1/2 to 1 inch in length and 1/4 to 1/2 inch in width. On susceptible plants the lesions increase rapidly in number. The lesions may merge, severely blighting and killing the leaves. A scale showing the six stages of blight severity which can be identified on the ground is shown in Figure 3.

The lesions on the stalk, leaf sheath, and ear husks may enlarge rapidly to as much as 6 inches in length. The penetration of the silk end of the ear or the shucks takes 7 to 14 days in damp weather, and may lead to a mold of the kernels and cob. The grain is destroyed. With severe leaf-killing, stalk rot by H. maydis and other fungi is increased. As a result there is much lodging where blight is severe.

The Blight Problem in 1971 - The prevalence and severity of only a few crop diseases can be accurately forecast months in advance of their onset. At the present time, SCLB is not one of these. No one could predict with certainty what the extent and severity of SCLB would be in 1971. However, in 1971 the Corn Belt was faced with the very real possibility of more severe and widespread corn blight damage than in 1970. First, there were sufficient supplies of resistant seed to plant only half of the crop. Second, the disease was already omnipresent at the start of the growing season; whereas in 1970 it had developed and spread in the Corn Belt in July and August. Third, normal moisture and temperature conditions in the Corn Belt would be extremely favorable to the development of blight.

Growers planted 5 to 20 percent more resistant, normal cytoplasm seed than had originally been expected. The distribution of the resistant seed played a significant part in the pattern of blight development in 1971. A relatively larger portion of the resistant seed was planted in areas hard hit by blight in 1970. Those areas which escaped serious blight damage in 1970 planted a larger portion of susceptible TMS cytoplasm seed (Figure 4). The most severely-infected areas of the Corn Belt in 1971 were those where there was very little TMS cytoplasm seed planted. In addition, the greatest acreages of corn occurred in those areas which had relatively little blight (Figure 5).

Weather, however, was the single most important factor in determining the severity of SCLB in 1971. A warm, dry spring enabled farmers to plant early. This, combined with favorable growing conditions in May and June, got the crop off to a fast start. In many areas the crop was nearly mature before blight infection reached significant levels.

Cool, dry weather from mid-July to mid-August significantly reduced the build-up of blight which might have otherwise been expected (Figure 6). In many areas across a large portion of the Corn Belt region, blight lesions were present on the lower leaves throughout July and August, but the cool temperatures greatly retarded further development of the disease, and were at the same time favorable for ear development and high yields.

Although widespread the blight was not nearly as severe as in 1970. The 1971 growing season produced the highest corn yields on record, but it should be noted that about 55 percent of the acreage in the Corn Belt had slight or mild levels of infection. Had the season's weather been warmer and more humid, blight development would have been as much or more than in 1970.

3. SAMPLING PLAN

The sampling plan involved the selection of the study area, determination of the flightline and segment sample design within the study area and determination of a field sample design.

A systems analysis approach was used in designing the Corn Blight Watch sampling model and data acquisition programs. Sampling decisions were not independent of data collection decisions. Decisions on ground data were never divorced from the impacts that those decisions would have on remotely sensed data.

Each decision was made by first defining the objectives for that aspect of the program. What was the goal for that aspect? What information or result was desired? How did each aspect meet the overall objectives of the experiment? How would the data collected be used?

Once the objectives for an aspect of the model had been defined, the resources available were itemized. In general, the resources used in the experiment were manpower, aircraft, and data processing facilities.

Once the objectives, resources and constraints had been defined, alternatives were drawn up and decisions made. In defining alternatives, people with expertise in particular aspects were consulted. Plant pathologists were contacted about the disease itself. People involved in planning large scale interview and field surveys were contacted about data collection forms and techniques. Aircraft people were consulted since the ground data collection had to be consistant with aircraft data gathering capabilities.

The result of this systems approach was an integrated model for sampling and data collection. For example, initial interview data from farmers provided not only the basis for selection of sample test fields, but provided auxiliary information for remote sensing interpretations.

Strict adherence to a sound sampling model enabled results of ground observations and analysis of photography and MSS to be expanded from individual field and segment estimates to estimates of the number of acres of each blight level present in the entire test area. The sampling model has also permitted an analysis of the cost and precision of many different combinations of flightlines, segments and fields to be made. Such information will be valuable in the future for optimizing sampling for remote sensing systems.

Selection of Test Area. The objectives used in selecting the test area in the Corn Belt were to include as much of the nation's corn acreage as possible and provide as wide east-west and north-south coverage as possible.

The main resources were the RB-57F and C-47 aircraft and enough manpower to collect data in approximately 200 segments.

The constraints on the size of the test area were the number of administrative units (states) involved versus the desired precision of estimates from collected data. Manpower and aircraft resources did not limit the size of the test area in themselves, but they did limit the amount of data which could be collected. Given that only so much data could be collected, precision of estimates would depend upon the size of the area sampled.

The test area decided upon included all of Ohio, Indiana, Illinois, and Iowa, the eastern crop reporting districts of Nebraska, the southern crop reporting districts of Minnesota and the northern and eastern crop reporting districts of Missouri. This area included 64 percent of the nation's corn acreage for grain in 1971. The test area provided an east-west magnitude of nearly 900 miles and north-south magnitude of nearly 400 miles.

The test area selected was not a homogeneous area in terms of cropping patterns. The percent of land devoted to corn varies greatly between states and within states. Field sizes tend to be larger in the major corn producing counties in Iowa, Illinois, Minnesota and Nebraska than in Missouri and Ohio. A large proportion of the corn fields in Ohio and Missouri and in parts of the other states are located close to woods. Some corn fields were located close to or in metropolitan areas. Topography and soil types varied greatly between and within states. Thus, the remote sensing applications of the Experiment involved interpretation of corn against many different backgrounds.

Segment Size Determination - Given a test area for the project, the next necessary step was determination of segment (test site) size and number of segments which could be monitored. Since SCLB affected different cytoplasms or corn to greater or lesser extents, it was desirable to have as many different cytoplasms present within a segment as possible. In order to reduce time and travel costs, a segment had to be no larger than a one-person assignment.

It was necessary to compromise statistical efficiency in order to provide fairly large segments. Adjacent farms tend to be very homogeneous in terms of proportion of land planted to corn, varieties planted and cultural practices. Therefore, the most efficient sampling procedure for estimates from ground data alone would have been to select a large sample of small segments spread throughout the test area. However, this allocation of samples could not be covered in a high altitude aircraft study without going to complete photo coverage of the test area.

Number of segments and size of segment were determined to a great extent by manpower. ASCS indicated a willingness to devote 1,000-1,500 man days to the project for field operations. It was assumed that this input might be matched by the Cooperative Extension Services of the various states. If interviewing took about one week and if 7 to 8 one-day visits were made for field observations, about 200 segments of land could be studied.

A segment size of one mile by eight miles was adopted. This provided a good compromise between ground data collection requirements and expected number of corn fields per segment.

Segment Sampling Design. The objectives in selecting the segment sampling design were to represent the total area and maximize the statistical precision from the number of segments.

With the limitation of having a relatively small number of large segments, a simple random or stratified random sample of segments would have given the most precise estimates. Selecting 200 counties based on the square root of expected corn acres would have given a good distribution across the test area. Establishing one segment in each county would have minimized ground travel time and cost.

Such an allocation of segments was plotted but it could not be covered within the time constraints of two weeks. It was necessary, therefore, to select a sampling plan based on the aircraft limitations. In order to provide photographic coverage within a two-week period, the maximum number of flightline miles was estimated to be about 4,000 if flightlines were 100 miles or longer and about 3,000 if individual lines were to be 50 miles or less.

The sampling plan was re-evaluated in light of the constraints imposed by the aircraft and a two-stage (flightline and segment within flightline) procedure adopted although this would limit the statistical precision of estimates from the experiment. All estimates would contain between-flightline and between-segment within-flightline variations. Since segments within-flightlines should be relatively homogeneous, the between-flightline variance components were expected to be large.

In order to increase the statistical validity of at least part of the Experiment, it was decided to sample a portion of the test area in the more optimum manner. In order to accomplish this, total photo coverage was requested for a portion of the test area.

The three crop reporting districts in western Indiana were selected as the area for the more optimum sampling scheme. Many of the resources available were concentrated in this area. Since the C-47 aircraft could not cover the larger area in a two-week period, all scanner flights were made in what was called the intensive study area. Thirty segments were designated for the intensive study area.

In the intensive study area three sources of data, ground observations, aerial photography and multispectral measurements, were compared using the more optimum one-stage sampling model.

The rest of the test area was sampled with 30 flightlines of approximately 100 mile lengths, each containing six segments. This gave a total of 210 segments (30 + 180). The total required flightline length was 4,000 miles.

Selection of Segments - Segments in both the intensive study area and the remaining portion of the test area were chosen by accounting for all land on maps and selecting the sample of segments from the total. In the intensive study area, this process involved a process of physically assigning all land to a specific segment. All of the segments were delineated on maps and a systematic sample of 30 segments chosen.

In the portion of the test area outside western Indiana, 1:1,000,000 aeronautical charts were divided into flightlines eight miles wide by approximately 100 miles long. A systematic sample of 30 flightlines was chosen. Each flightline was then divided into segments one mile by eight miles. A sample of six segments was chosen in each flightline.

Sample Field Selection - The goal in selection of fields for visits during the growing season was to represent the different cytoplasms present in each segment. However, the number of fields per segment had to be limited to a number which could be visited in one day.

Eight to ten fields was felt to be a reasonable maximum number of fields for an assignment. Once units were established within a field the field observer returned to the same units each time. Since detailed observations were to be made on only five plants in each of the two units in the field, it would not take long for the observations.

The strata used for sample field selection were (1) normal cytoplasm (resistant to SCLB) only, (2) Texas male sterile (susceptible to SCLB) cytoplasm only, (3) blends of normal and Texas male sterile only, (4) F-2 or open pollinated (non-hybrid) fields and (5) combinations of the other strata planted in a field plus unknown cytoplasms.

Two fields were selected from each stratum present giving a maximum sample size for a segment of ten fields. The maximum in most segments was eight fields since F-2 and open pollinated fields rarely occurred. In the intensive study area the sampling rate was increased to 12 fields per segment.

It was envisioned that nearly all sample corn fields might be needed for training by photo-interpreters and scanner analysts. There would be few, if any, fields with ground data left for testing of classification results. Therefore, an additional sample of fields was selected in 24 segments. These additional fields were worked by ASCS personnel and could be used for testing by individual interpreters and analysts. Also, they would provide insurance that adequate ground data was being collected in at least part of the segments in case more data was needed for training.

4. DATA ACQUISITION

Data acquisition for the CBWE included ground and aerial data. Ground data consisted of baseline data collected during the Initial Interview Survey and blight data collected during the Field Observation Survey. Aerial data consisted of small scale photography and multispectral scanner data.

Ground Data Collection

Initial Interview Survey - The objectives of the initial interview survey were to (1) identify crop or land use in each field within segments, (2) collect information on corn fields for sample selection, and (3) collect information which might be helpful in remote sensing interpretations.

Each farm operator in the segment was identified and interviewed. Each of his fields was delineated on aerial photography prints and numbered. Acreage and crop or land use was recorded for every field. Nonagricultural areas within the segment were delineated, but no information from them was processed.

Additional information was collected for each corn field. Specific questions were asked about the field and its susceptibility to SCLB. These included cytoplasm of corn planted, variety of corn, whether corn was planted in the same field the previous year and if blight was apparent in corn fields the previous year. The remaining questions were intended to provide information for interpreting the appearance of each corn field on remote sensing images. These questions included planting date, row width, plant population, row direction, and whether the field would be irrigated.

The initial interview were conducted by personnel in the county offices of the Agricultural Stabilization and Conservation Service, USDA. These personnel were experienced in contacting farm operators and in the use of aerial photography.

All interviewers attended a one-day training school. All aspects of the survey were covered in these intensive training sessions. Four-man teams from the participating agencies conducted the training schools.

Over 8,000 interviews were conducted by some 300 ASCS personnel during a 10-day period. Information on land use and acreage was obtained for over 56,000 fields.

<u>Field Observation Data</u> - The Field Observation Survey was designed to obtain the following four types of information to describe the conditions in two randomly selected units within the sample fields:

1. The amount of vegetation present.
2. The presence and severity of Southern Corn Leaf Blight.
3. The presence and severity of other crop stresses.
4. Crop maturity and other information which might affect photography and scanner imagery.

To obtain estimates of the amount of vegetation present, the following items were recorded: row width, number of plants in 30 feet of row, number of leaves per plant on five plants in the unit, and length and width of the leaf at the seventh node of each sample plant. From these items plant population and leaf area index could be calculated.

Data for estimating Southern Corn Leaf Blight infection were obtained in two ways: (1) Placing each of the five sample plants in unit 1 and 2 into a blight severity class from zero (none) to five (very severe), and (2) counting the number of lower and upper leaves with lesions and estimating the percentage of lower and upper leaf area covered by lesions. A blight severity rating was then calculated from the information in (2).

Other stresses such as drought, weediness, lodging, hail damage, insect damage, other diseases and nutrient deficiency were identified. Specific comments describing the kind and extent of stress were requested of the field observers to aid in the interpretation of the sample fields on photographs and scanner imagery.

Other information which might aid remote sensing interpretation included information on the stage of maturity and uniformity of the field. The field observer compared the randomly selected units with the portion of the field surrounding the units in determining whether the units were representative of the field.

The basic requirements of the field observation procedures were that data should be repeatable and consistent. If two people were sent to the same field independently, the results should be the same. Thus, variation in observations were due to physiological changes, not sampling variations. In order to have repeatable and sequentially consistent data, certain plants or areas of each field were defined and marked. Procedures were designed so that each observer located and marked the two random sample units in exactly the same manner.

Yield Survey - As the growing season progressed there was increased interest in obtaining yield information from the sample fields. As a result, ears from the sample plants observed during the season were harvested and sent to LARS where they were dried, shelled, weighed and yield estimates calculated.

The information from each field was not expected to be sufficient to accurately estimate the yield of that field; it would take many random samples within a field to arrive at such a figure. However, the data from all similar fields, taken as a group, did give an accurate description of the effect of blight on yield.

Aerial Data Collection

The NASA Manned Spacecraft Center supported the Corn Blight Watch Experiment by acquiring remote sensor data with the dedicated use of the RB-57F and the University of Michigan C-47. The RB-57F collects photography at altitudes of 50,000 to 60,000 feet. The C-47 is equipped with a 12-channel multispectral scanner. The Project was organized into 3 phases based on the mission objectives and imagery required.

The objective of the Phase I, conducted in April, was to acquire current black and white photography to provide enlarged prints of each test segment. These prints were sent to USDA and used for the Initial Interview and Field Observation Surveys, as well as by data analysts.

In May, the RB-57F obtained color infrared photography while the C-47 obtained multispectral scanner data for soils background information. This was termed Phase II.

Finally, the two aircraft collected color infrared photography and multispectral scanner data over their respective flightlines and segments repetitively throughout the growing season. This was known as Phase III and extended from mid-June through September.

RB-57F Mission Requirements - Aerial coverage by the RB-57F included extensive areas of Ohio, Indiana, Illinois, Iowa and portions of Minnesota, Nebraska, and Missouri. Two hundred and ten test segments were defined along 38 flightlines.

Approximately 3800 flightline miles of data were flown during Phase I and Phase II as well as bi-weekly during Phase III. Each flightline was independent except in western Indiana where eight parallel and overlapping flightlines provided contiguous coverage of the intensive study area. Phase I flights were flown at 50,000 feet to provide a convenient scale for subsequent enlargements. Phase II and III were flown at 60,000 feet for optimum aircraft endurance and sensor coverage.

Data acquired by the RB-57F during Phase I was Aerographic Type 2402 black and white photography which was provided to USDA in the form of 24" x 35" paper prints enlarged to a scale of 1:20,000. Aerochrome infrared type 2443 color infrared imagery was acquired by the RB-57F during Phase II and III. Duplicate positive transparencies and color prints were provided to the Data Reduction Center. Delivery of processed imagery to LARS was required with minimum delay to permit analysis of photographic imagery in conjunction with ground observations.

RB-57F Mission Planning and Operations - Planning the RB-57F portion of the project was similar to most previous operations with two major exceptions. These exceptions were data quality and data delivery.

Color infrared imagery obtained from previous RB-57F missions had often been nonuniform in exposure over multiple frames and within frames due to factors such as sun angle and atmospheric effects. Nonuniformity also occurred from frame to frame due to sun angle and scene brightness changes. This made analysis difficult, particularly since the interpreter was looking for subtle tonal differences. To reduce exposure nonuniformity, changes were made in camera operation and processing techniques. While these efforts did not eliminate the problem, they did result in improved data products. The north-south flightline orientation did permit optimum use of photographic overlap. A single emulsion batch of color infrared film was obtained to reduce the tonal variations anticipated if more than one emulsion batch was used during the Project.

Two problems occurred with the selected infrared film. Early in Phase III, an abnormal spotting condition was detected on the color IR imagery. The defect was termed "cyan spotting" because the mottled appearance of the imagery was caused by a defect in the cyan layer of the emulsion. The cyan spots occurred randomly and made analysis of the imagery difficult. During the Experiment, supplemental film was flown to partially overcome the cyan spotting problem.

In addition to the cyan spotting problem, the selected color IR film lacked adequate range in infrared tonal variations. In other words, the film was too saturated. This problem, also, was partially eliminated by the use of film with a less sensitive infrared emulsion.

Timely delivery of the data to LARS presented a difficult problem. A data management plan was prepared in order to meet the required delivery dates while minimizing the impact to ongoing programs.

Weather is a critical factor in planning aircraft remote sensing missions. The Corn Blight Project made greater use of long range weather planning guides in order to estimate the scope of coverage that should be attempted. Day to day mission operations were conducted with the assistance of an onsite meteorologist who monitored weather conditions and was prepared to advise the aircrew on the most suitable test site areas. While no attempt was made to compare actual versus forecast weather, the success of the data acquisition indicates that both long and short term weather forecasts are essential to mission planning and operations.

A factor that increased the operational flexibility of the RB-57F and directly affected the success of the mission was the use of a standard sensor configuration. This eliminated sensor configuration changes in day to day operations and permitted data acquisition limited only by weather conditions, film capacity, and aircraft endurance.

In summary, the RB-57F efforts resulted in the completion of 85 percent of the required coverage with less than 30 percent cloud coverage affecting the imagery. Fifty-four flights were flown over the Corn Belt. Four hundred hours of flight time were expended on the Corn Blight Watch which is approximately 2/3 of the annual RB-57F flight time allocation. Thirty percent of the available mission time was lost due to unsuitable weather, 20 percent was lost due to unscheduled maintenance, and 5 percent was lost due to scheduled maintenance. A 50 percent utilization factor is probably a good planning figure for future missions under similar conditions.

<u>C-47 Mission Planning and Operations</u> - The University of Michigan C-47 was also dedicated to the 1971 Corn Blight Watch Experiment. The C-47 provided Phase II and Phase III coverage of the 30 test segments within the ISA with the 12 channel multispectral scanner, and supplemental photography. Phase II coverage was coincident with the RB-57F Phase II operations. Phase III operations began in late June and continued bi-weekly until early October. The 30 test segments were flown individually at 5,000 feet.

Operational criteria were established to provide acceptable multispectral scanner data. These criteria specified that visibility at the flight altitude must be at least 6 miles with less than 30 percent cloud cover above the aircraft and less than 15 percent below the aircraft. The minimum acceptable sun angle was 50 degrees although this limit could not be met later in the mission. These criteria proved to be satisfactory; however, an additional constraint was added later in the mission. It was determined that an excessive aircraft drift angle was unacceptable due to excessive image distortion. A limit of 15° drift angle was imposed to reduce the image distortion to acceptable levels.

In summary, 98.4 percent of the sample areas were satisfactorily completed by the C-47. One hundred and fourteen flight hours were expended.

In conclusion, for both the RB-57F and C-47, the project was different than previously planned missions in duration, coverage, and sensor configuration. The wide area coverage and single sensor configuration provided flexibility in mission operations that greatly contributed to mission success.

The project provided a unique opportunity for review of the data on a timely basis permitting sensor corrections to be made and evaluated in the field.

The Experiment was also provided an excellent prelude to future support of complex aircraft and spacecraft missions.

5. DATA HANDLING AND ANALYSIS

Data Flow

The Corn Blight Watch Experiment was conducted in three phases. The data flow is best presented by describing the transfer of data from data acquisition centers to and between the data processing centers for each phase. The data flow plan is graphically shown on diagrams which include each center and each transfer of data between the centers.

Phase I - During Phase I, baseline data for the entire Corn Blight Watch Experiment were collected between April 15 and May 15. Data acquisition for Phase I included the collection of black and white photography. Processing included the reduction of photography to a scale of 1:20,000, the outlining of tracts and fields on the reduced photography, and the reporting of farm operator interviews through SRS to the data reduction center at LARS. Figure 7 shows the data flow for Phase I.

At SRS the segment was outlined on one copy of each print and this was sent with initial interview forms to the Agricultural Stabilization and Conservation Service county enumerators. Each farm operation in the segment was outlined and visited by the ASCS enumerator. During the interviews a field ID was assigned to each field, field boundaries and ID annotations were added to the photograph, and the initial interview forms were filled out for each field in the segment. The annotated photographs and completed initial interview forms were copied onto the other two sets of prints and the data on the forms were coded, punched, edited, and recorded in digital format. One set of baseline photographs and a digital copy of the initial interview data were sent to the Data Reduction Center at LARS. A second set of baseline photographs was sent to the Cooperative Extension Service in each state where segments were located.

Phase II - In Phase II, between May 10 and May 30, color IR photography was collected over the 210 segments and multispectral scanner data were collected over the 30 intensive study area segments. These data were analyzed for soils characteristics to provide soils background information for corn fields in the segments. The flow diagram for Phase II is shown in Figure 8.

Phase III - Eight missions were conducted during Phase III between June 14 and October 13, 1971. During this phase, color IR photography was collected every 14 days over all 210 segments and multispectral measurements were collected every 14 days over the 30 segments in the intensive study area. Early in each 14-day period, ground observations of up to 12 corn fields in each segment were acquired. These data were processed and sent to the data reduction center at LARS. Fifteen segments of multispectral data and ground observations were sent to the data reduction center at WRL. The photographic and multispectral data were analyzed and results were reduced and reported to SRS in Washington and to the other participants in the Corn Blight Watch Experiment. The major data transfers for Phase III are shown in Figure 9.

During Phase III a new mission was started every other Monday, June 14, June 28, July 12, July 26, August 9, August 23, September 6, and September 20. Each mission was completed in 21 days and results were punched, checked, collated, and reported 23 days after the mission began.

The biweekly field observation reports were sent to the SRS state offices during the first week of the period, and, for the 30 segments in the intensive study area, reports were also phoned to the Data Reduction Center. At the SRS state offices data were edited, coded, and punched onto data cards. At SRS in

Washington, they were error checked, copied onto digital data tapes, and listed on ground observation printouts. The biweekly data were delivered to the Data Reduction Center, and Ground Observation Summaries, described later, were distributed to the analysis teams by day 10 of each biweekly period, the same day as photographic data were available.

Analysis Procedures

Each of the data analysis teams was given a Ground Observation Summary for the segments to be analyzed or interpreted. A new summary was distributed each period so that pertinent information required for analysis would always be available. Although the form of the summary was the same each period, parameters listed were added or dropped according to the needs of analysis teams. In the flight information area of the summary, the segment number, film roll number, frame number, date and time of the flight, and flight direction were listed. Next information for the corn fields visited biweekly was listed as well as some information for all other corn fields and non-corn fields in the segment.

Photointerpretation - With the film roll transparencies mounted in the Variscan, a rear projection system, the frame indicated by the Ground Observation Summary could be located by a photographic analysis team as shown in Figure 10. Using the summary and the baseline photograph, the biweekly corn fields were located and studied so the teams could train themselves on the appearances of blight levels in the segment. The number of fields used for training varied during the experiment; not all biweekly field information was used.

Next each corn field in the segment was located and interpreted, and the results recorded on a recording form. These results were coded, punched, edited, and added to the Corn Blight Record for each of the 210 segments. The six teams of photo analysts completed their analysis by day 23 of each period. On the average each segment was analyzed one week after the data collection date.

Multispectral Data Analysis - Fifteen segments out of 30 in the Intensive Study Area were analyzed by LARS. The analog tapes were digitized and displayed on a digital display. Figure 11 shows an analyst locating the biweekly fields using a baseline photograph and lightpen. The data from the biweekly fields were analyzed using a clustering procedure, and the results were used to determine classes for the analysis and data points for generating class statistics. Next the channel selection program was used to pick four optimum channels for classification at Purdue and six optimum channels for classification at WRL. In general all channels of data collected were used during the season. There was no single best set of channels; however, a thermal channel, two reflective IR channels and a visible channel were usually selected for classification of the segment. At WRL a similar procedure was followed using analog techniques on the other 15 segments in the Intensive Study Area.

Results for all 30 segments were reported both on a total segment basis and on a field-by-field basis with LARS and WRL using the same reporting forms. The entire segment was classified into non-corn and corn classes of different blight levels. This is a more complicated classification than interpreting blight levels only in corn fields. The multispectral scanner results were also completed by day 23 of the period and were finished an average of 10 days after the segments had been flown. These results were also recorded on the Corn Blight Record. Detailed descriptions of the LARS and WRL analysis procedures may be found in other reports.

Corn Blight Record

A record of the information obtained for every field in each of the 210 segments was maintained on digital tape. The system designed for accomplishing this task and implemented for the Corn Blight Watch Experiment was called the Corn Blight Record and is shown in Figure 12. The initial interview data and biweekly field observations were merged with flight log information, multispectral analysis results, and photointerpretation results. The resulting tapes, one for the seven state area and one for the intensive study area, were the source of most of the listings and tabulations generated during the experiment.

Data analysis results in the form of tabulations were generated on day 23 of each period for SRS in Washington. Expansions of results according to the sampling model were also generated for each period for ground observations, photographic analysis, and multispectral data analysis. Breakdowns of blight results by cytoplasm and for many other parameters were made. Yield calculations were also made. In addition, the results were analyzed using standard statistical techniques such as correlation and analysis of variance.

Results Summarization and Dissemination

In Figure 13 the data flow for dissemination of the blight analysis results is summarized. For each biweekly period, color IR photographs were sent to the county enumerators for their particular segments. Questions and training materials were sent with the prints and results were returned for evaluation. The purpose of this aspect of the experiment was to acquaint the enumerators with small-scale photography.

Summarization of ground observations was performed by SRS within one week of data collection. Photographic and multispectral analysis results were sent to SRS within an average of two weeks after data was collected. These results were available to SRS for compiling blight reports to the USDA information center which in turn handled press releases to the news media.

6. EXPERIMENT RESULTS

Blight Detection and Mapping

The development of blight in the Experiment test area is shown in Figures 14 to 16. Through July 30 the average blight severity was only none to slight over the entire area. In T-cytoplasm fields mild levels of infection were developing in Missouri, southern Illinois, and southern and west-central Indiana (Figure 14).

Two weeks later there had been a further increase in the prevalence and severity of blight infection with some areas of severe infection present in Illinois and Indiana (Figure 15). By the last week of August blight infection had become more widespread with at least mild levels present in much of the eastern Corn Belt area. Figure 16 shows the areas in Illinois and Indiana where blight was most severe in T-cytoplasm fields. Although there was some increase in the severity of leaf infection in September, most of the crop was nearly mature and further infection had little or no effect on yields.

The development of blight during the 1971 growing season is summarized in Figure 17. At the end of the growing season less than 20 percent of the acreage had moderate or severe infection levels and only about five percent of the crop was severely infected (Figure 18).

Although the 1971 growing season produced the highest yields on record, it should be noted that about 55 percent of the acreage in the Corn Belt had slight or mild levels of infection. Had the season's weather been warmer and more humid, blight development would have been similar to 1970.

<u>Photointerpretation Results</u> - The photointerpretation results can best be examined by comparing the photointerpretive estimates of blight severity with those made from ground observations. The first level of comparison will be estimates of total number of acres in each blight severity level for the entire experimental area (Figure 19). There is close agreement between the two estimates at all blight levels except 0 and 1. The higher number of acres of blight level 0 estimated by photointerpretation indicates that slightly infected corn could not be distinguished from corn with no infection using photointerpretation techniques; therefore, corn with level 1 infection was probably called blight level 0 (healthy corn) in many cases. The variances for field and photointerpretive estimates are of similar magnitude.

Photointerpretive and field observation results can also be compared at the flightline level. The average blight severity level for each flightline according to ground or photointerpretive estimates was computed from the expanded acreage of corn in each blight level in the flightline. Figures 20 and 21 make these comparisons for the period beginning August 9 and August 23.

During the two-week periods beginning August 9 (Figure 20) and August 23 (Figure 21) the photointerpreters tended to over-estimate the average blight levels relative to ground estimates. This was largely due to the difficulty of distinguishing blight effects from effects caused by other factors which appear similar to blight damage on the infrared film. Some of these factors include other diseases, drought damage, insect damage, and nutrient deficiencies. Work is continuing to further quantify the similarities and differences in appearance of these factors on color infrared film.

Unfavorable weather prevented collection of photography over the eastern half of the area during the period from September 6-19. For those flightlines where comparisons could be made, there was good agreement between ground observations and photointerpretation results.

Although ratings of blight severity were made in many fields across the Corn Belt, an average of only eight fields per segment were checked on the ground. Most of these fields were used for training. To make the best tests of classification accuracies, ratings would be needed from many more fields so that field by field comparisons could be made. However, only a limited number of fields were available for this kind of test. Therefore, other kinds of statistical analysis have been used to evaluate the classification results. One of the procedures used was correlation. Correlation is a quantitative measure of the degree of agreement between the two methods, both of which are known to be subject to experimental error. Close agreement between field observations and photointerpretation (or machine analysis of multispectral scanner data) means that the two methods are estimating the same value for the parameter.

To more quantitatively illustrate the same data shown on the previous maps, plots of field observation estimates versus photointerpretive estimates are presented in Figure 22 for two periods. Segment means are shown in Figure 22 whereas flightline means were shown in the previous figures. Note that there is an increase in the correlation coefficient (r) for the later period when more levels of blight were present. The 1:1 line is shown as an aid in determining when there is good agreement between the two methods; it should not be confused with a regression line. Perfect agreement between the two methods would result in all points falling on the 1:1 line. A consistent bias (either over- or under-estimation) would still result in high correlation.

A major objective of the experiment was to determine if healthy corn could be distinguished from diseased corn by remote sensing methods. The graph of correlations for two classes of blight severity (0-1-2 and 3-4-5) indicates that the corn fields could be accurately separated into the two classes, healthy or slightly blighted and moderately to severely blighted (Figure 23). The data points in Figure 23 represent acres of each blight severity class in a segment. Correlation coefficients of .90 and .64 were obtained for the two classes, respectively. There was a tendancy for photointerpretive results to underestimate the acreages in the healthy corn class and overestimate the acreages in the moderate to severe blight class as compared to ground estimates. Attempts to differentiate the six individual blight classes which can be distinguished on the ground were unsuccessful. This was indicated by low correlation coefficients ($r = .21$ to $.67$), the "scatter" of the data points, and large deviation from the 1:1 line. This is not surprising since differences between individual classes are subtle. The early stages of infection are confined to the lower leaves which are hidden from the view of the sensor.

Several photographic variables may have affected the photointerpretation results and complicated the task of blight assessment by photointerpretation. Changes in illumination conditions, haze, terrain features, and other factors could not be controlled. Problems with oversaturation and cyan spots have already been discussed.

Machine Analysis of Multispectral Scanner Data Results - In the intensive study area multispectral scanner data were collected along with ground observations and color infrared photography. A comparison of three methods of estimating the total acres in each blight class for the entire intensive study area is shown in Figure 24. The ground estimates and machine analysis estimates agree closely and have similar variances. Using photointerpretation techniques blight level 1 was greatly underestimated and blight level 3 overestimated compared to the other two methods.

The correlation of segment average blight levels as estimated by field observations and machine analysis of multispectral scanner data are shown in Figure 25 for two periods. There was much better agreement between the ground observations and machine analysis results as evidenced by higher r values (.86 and .90) and the close fit to the 1:1 line than for the photointerpretation results. As shown earlier for photointerpretation, the two earliest stages of blight infection were difficult to detect remotely.

The separation of fields into either healthy or blighted categories is shown in Figure 26. There is excellent agreement between the field observations and the estimates made from analysis of multispectral scanner data. The data are the number of acres in each blight class for each of the 30 segments in the intensive study area. Correlation coefficients were .94 and .92 for the two classes and the points lie close to the 1:1 line. Attempts to classify the number of acres in each individual blight level were less accurate than for either two or three classes.

There are a number of reasons for what may seem like a poor performance. One is that blight infection is a continuum and does not fall into discreet classes; this can lead to confusion on the ground as to what the true blight class is when, for instance, it is between mild and moderate. Another is that blight, although a dominant factor, was only one of many other factors causing variability in the spectral response of corn fields. These include differences in cultural practices such as plant population, row width and direction, crop maturity, and morphological characteristics of the hybrid, to name only a few. The soil background also often varies considerably from field to field and even within fields. Other factors leading to confusion in blight identification included in some instances the presence of other stresses such as drought damage, nutrient deficiencies, and other diseases which may be spectrally similar to SCLB.

But perhaps more important than the differences introduced by the ground scene are those resulting from variations in the radiation sensed which are not due to changes in the characteristics of the objects being sensed. The primary source of variation is the atmosphere. Other important causes are solar angle and view angle. The effect of these variations is to cause similar objects to exhibit different apparent spectral signatures. The result of this is that training fields are good for only very localized areas. In the Corn Blight Watch there were many instances when there were not sufficient training fields available to describe all of the blight and other conditions known to be present. Data processing techniques need to be developed which allow the extension of spectral signatures over larger areas.

Both LARS and WRL have been conducting research in these critical areas. Both laboratories have used methods whereby the average signal variation as a function of scan angle is computed for each spectral band. Much of the angular variation in the signal can then be eliminated by dividing each scan line of data by the normalized average signal variation. A significant reduction in signal range of corn and other cover types has been accomplished by the application of these relatively simple techniques with the result that crop signatures were more unique and easier to differentiate. Thus far, it has not been possible to determine if the subtle blight level discrimination was affected.

Work has also been underway at both laboratories on other facets of the signature extension problem. At this time it can only be reported that there is reason for cautious optimism that signatures can be successfully extended over time and space, but more effort will be required before these techniques will be operationally useful. More detailed reports of this and other data processing-analysis research can be found in publications by WRL and LARS.

Influence of Blight on Yields

In most of the test area blight did not seriously affect corn yields. In fact, state average yields were the highest ever recorded. There were, however, certain restricted areas where blight did significantly reduce yields. Of the fields for which yield estimates were made, 91 T-cytoplasm fields had blight levels 3, 4, or 5 during the August 23-27 observation period when ear filling was occurring. Twenty-four of these fields had moderate to very severe blight levels on July 26-30; they produced an average yield of 71 bushels per acre. Those that had none to only mild blight on July 26-30 had an average yield of 97 bushels per acre. The blend fields from the same segments had mild to moderate blight levels and had an average yield of 118 bushels per acre; while the normal cytoplasm fields yielded 130 bushels per acre. It is significant that the blight classes which could be accurately detected remotely were the same as those which significantly affected corn yields.

Crop Identification

An important part of the Experiment was an evaluation over a large area of the accuracy with which crops could be identified by remote sensing techniques. Major crops were accurately identified throughout the season (Table 1) by both photo-interpretive and machine assisted analysis techniques even though this aspect of the Experiment received relatively little emphasis compared to the more difficult blight detection problem. These results give reason for optimism regarding the feasibility of operational remote sensing crop survey systems.

It was also possible in certain instances to identify several key factors affecting corn productivity. These included low population, drought damage, hail damage, extreme weediness. There were other times, however, when these factors undoubtedly could not be differentiated from the effects of blight. Overall blight severity within individual fields was found to be quite uniform; whereas, the factors mentioned above tended to be more irregular in appearance across the field.

7. DISCUSSION

The significant results of the 1971 Corn Blight Watch Experiment can perhaps be best expressed by summarizing how well the application objectives were achieved and by discussing the performance of the key elements of the technology relative to those achievements.

The application objectives required (1) the detection of outbreak, identification of temporal increases in severity levels and the tracking of spread of SCLB over the total study region; (2) an assessment of the impact of SCLB on production; and (3) an estimate of the applicability of remote sensing to other situations which would require surveys on a large scale.

With reference to the first objective, it can be concluded that neither the manual interpretation of small scale photography nor the machine-aided analysis of multispectral measurements adequately provided detection of SCLB during early stages of infection. Analysis of these data did, however, permit the detection of outbreaks of moderate to severe infection levels and mapping of the spread of those levels over the study regions with relatively high accuracy.

Analysis of data acquired in 1971 showed that the variation in the presence and extent of different infection levels increased as the geographic separation between sample areas increased. This leads to a conclusion that a more accurate assessment of conditions due to SCLB could have been realized with a smaller set of data samples had smaller samples been better distributed over the total study region.

As far as the second objective was concerned, investigators were able to associate significant yield reductions with moderate to severe infection levels occurring in August and still greater reductions associated with moderate to severe infection levels occurring in July. The results of the experiment indicate that acreages infected at these levels were identified in the late July and August periods with relatively high confidence.

And finally, results in the area of the third objective clearly indicate that the technology is capable of both reliably identifying and measuring the extent of agricultural crops and land use. Furthermore, it can be concluded that the technology is suitable for detection of crop stress in those instances where the stress changes the radiation characteristics of the crop.

The Corn Blight Watch Experiment provided an excellent opportunity to evaluate all aspects of a system designed to collect, analyze, interpret, and distribute information repeatedly at short intervals throughout a growing season.

While it raised as many questions as it answered, it produced extremely valuable guidelines for future research and development.

An important result of the experiment is the file of photography, multispectral measurements, and field observations collected at biweekly intervals over an entire Corn Belt growing season. This data set is available, and will prove extremely valuable in further studies.

Another important part of the Corn Blight Watch Experiment was the knowledge gained about the costs of a large scale information system using remote sensing. The information on the cost in dollars and time for each part of the experiment will be useful when future experiments or operational systems are planned. These data on labor, computer costs, aircraft, film, processing, etc. expended in the experiment are being used to investigate the relationship between subsampling ratios, costs, and precision of estimates.

The Corn Blight Watch Experiment also demonstrated the value and effectiveness that can be achieved by pooling the resources of a number of cooperating groups. No single organization has at this time the expertise or resources to go it alone in such an effort. Certainly, the Watch provided much valuable data related to the resources required to implement this type of program and insight into the practices and procedures which are most effective in the design and operation of such systems.

Because of the Corn Blight Watch Experiment many agriculturists had an opportunity to work with remote sensing information. The majority of field personnel responded favorably to the aerial color infrared photography sent to them and reported that it could be used to good advantage in their work.

The Corn Blight Watch Experiment demonstrated that a statistical sampling model is a fundamental element of a remote sensing survey system. A general conclusion is that additional effort needs to be expended to develop sampling concepts suited to remote sensing data acquisition systems and automatic data analysis procedures. As a part of the Corn Blight Watch investigators did gain valuable experience developing a capability for setting up survey prediction models utilizing remotely sensed measurements.

The data acquistion elements performed well. The Experiment provided evidence that a fully-committed, high-flying aircraft can effectively acquire data at biweekly intervals for a region as large as the Corn Belt. Furthermore, this was accomplished under the less-than-optimum Corn Belt weather conditions. The University of Michigan C-47 was similarly able to collect multispectral measurements over a 13,000 square-mile area in western Indiana. In contrast, only a comparatively small amount of data was acquired by the large number of ground observers.

Another significant facet of the Experiment was the demonstrated capability to reliably identify crop types over a significantly large area with today's technology. Foreseeable performance improvements over the next several years promise still greater accuracies.

Considerable manpower was required to determine the identification of the crop types and acreages within each of the 210 segments. This was accomplished by ASCS state and county personnel. These data were required as inputs to the sample model. However, considerable savings in manpower can be realized by obtaining these data through remotely sensed measurements. Results of the Corn Blight Watch indicate that crops can be reliably identified by either photointerpretation of small scale infrared photography or through computer processing of multispectral measurements. However, if acreage measurements are to be obtained from scanner data, additional techniques need to be developed. Such efforts need to be undertaken in the near future. It is possible, for instance, that a capability to register different data sets required for temporal analysis would also solve the area determination problem. Multispectral data sets would be registered to a photogrammetrically-corrected data base. Area measurements could then be made from the geometrically-corrected multispectral data classification output. It should be noted that, currently, the acreage in a field is either estimated from the ground or manually measured on black and white photography. Certainly remote sensing presents a more efficient alternative.

Additionally, much was learned about how to acquire information over a large geographic region with manageable data volumes. The use of a statistically sound sampling model was shown to be a key element in accomplishing this.

Other solutions and suggestions include the fact that a helicopter proved to be a valuable aid in acquiring field observation data. Such a system can often permit a more accurate assessment of more fields in shorter periods of time than conventional ground surveys.

Also, results indicate that much more would be gained from the development of techniques which would make possible the acquisition of photography having more consistent exposure from mission to mission. Similarly, improved preprocessing techniques would provide more useful multispectral data over a wider range of conditions (i.e., atmospheric and sun angle effects).

The Corn Blight Watch Experiment resulted in significant improvement of aerial infrared film. The condition which caused the "cyan spots" and hampered the analysis because of their similarity to blight has since been corrected. This deficiency in the film was discovered by the photo-analysts of the Experiment.

The Experiment demonstrated the need for more agriculturists with training in photo-analysis. It is hoped that more schools of agriculture will provide and encourage their students to take course work in remote sensing. If photography is to be utilized in agricultural situations it is imperative to have people trained to work with the data.

Results also lead to a conclusion that machine assisted analysis of multispectral scanner data was more effective in detecting, tracking the spread and assessing the impact of SCLB than was the photo-analysis of the small scale photography. This was expected since the photo-analysts were looking for small tonal color changes in the crop. The multispectral sensor produces a better measurement of these spectral changes and the data are more amenable to machine processing routines.

However, the results indicated that if either remote sensing approach is to offer a decided advantage over ground acquired data, ways must be found which require less ground truth for the initial selection of training samples and techniques developed which permit the use of statistics derived from training samples to a wider range of conditions and over larger geographic distances. In many instances, (especially in those cases involving visual phenomena) it is believed that selected high resolution photography could replace the need for much ground acquired data in the selection of training samples.

There is a need for further work establishing the statistics of the spectral patterns of natural scenes to better determine the causes of variations (including sun angle, observation angle, and atmospheric effects) described by those statistics. It is believed that variations in response not due to the ground scene led to the relatively low accuracies which were achieved over small areas (10's of square miles). The variances were sufficiently large to require samples over relatively large areas before accurate estimates were realized.

Again, results from the Corn Blight Watch indicate that considerable improvement in performance could have been realized had the analysis had the capability to consider temporal variations of spectral patterns. In this light, there continues to be a strong need to be able to automatically make coincident data sets collected at different times. As an example, more is to be gained from eight channels of data collected at three different times than 24 channels collected at one time. It should be noted that data registration is the key to this type of analysis.

An examination of the physical characteristics of SCLB (uniform infection within a field) indicates that improved results could have been obtained with sample classifiers as opposed to the point classifiers currently being used. Before such classifiers can be employed, however, techniques need to be developed to automatically identify the boundaries of data fields.

In the space and time available in a paper of this nature it is impossible to present all of the results of an experiment as large as the Corn Blight Watch

Experiment. It has been possible to present only a brief overview of the more important aspects of the Experiment. A complete description of its implementation and all results will be included in the Final Report of the Experiment.

8. SUMMARY AND CONCLUSIONS

The 1971 Corn Blight Watch Experiment provided a prototype remote sensing system in which techniques of data gathering, storage, retrieval, processing and analysis and information dissemination were successfully used in one integrated system operated in a quasi-operational environment. The experiment effectively focused the efforts of many disciplines and agencies on a common problem and resulted in many people becoming acquainted with remote sensing techniques.

In conclusion, accurate identification of agricultural crops and land use over large geographic areas using remote sensing techniques was clearly demonstrated. The potential utility of these techniques to assess crop stress over large geographic regions was also demonstrated. The 1971 Corn Blight Watch Experiment provided the most quantitative information available on the extent and severity of blight.

But most important, the Experiment was a major milestone in the development of earth resources survey by remote sensing. Existing remote sensing techniques were refined and many new ones implemented as remote sensing moved a step further into the real world.

Finally, the Experiment provided valuable direction for future research and development of remote sensing technology and guidelines for the design of operational information systems utilizing remote sensing.

9. REFERENCES

1. The 1971 Corn Blight Watch Experiment. A series of seven papers presented at the 4th Annual Earth Resources Program Review. Houston, Texas. January 17-21, 1972. Volume V:124-1 to 131-5.

2. 1971 Corn Blight Watch Experiment, Final Report. To be published, January 1973.

10. ACKNOWLEDGEMENTS

The 1971 Corn Blight Watch Experiment was the cooperative effort of many federal, state, and local agencies. The contributions of each of the agencies and of the many individuals who participated in the Experiment is gratefully acknowledged. The agencies which participated in the Experiment included:

United States Department of Agriculture
- Agricultural Stabilization and Conservation Service
- Statistical Reporting Service
- Economic Research Service
- Cooperative State Research Service
- Agricultural Research Service
- Extension Service

National Aeronautics and Space Administration
- Headquarters
- Manned Spacecraft Center
- Ames Research Center

Cooperative Extension Services and Agriculture Experiment Stations of the States of Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, and Ohio.

University of Michigan, Willow Run Laboratories

Purdue University, Laboratory for Applications of Remote Sensing

TABLE I. IDENTIFICATION OF CORN AND OTHER CROPS BY PHOTOINTERPRETATION OF SMALL-SCALE INFRARED PHOTOGRAPHY AND MACHINE ASSISTED ANALYSIS OF MULTISPECTRAL SCANNER DATA.

	Analysis Method		
	Photointerpretation		Machine Assisted
Date	Corn	Other[1]	Corn vs. Other[2]
June 14	73	60	-
June 28	85	54	79
July 12	92	50	89
July 26	89	40	91
August 9	93	60	88
August 23	91	60	86
September 6	96	58	88
September 20	96	58	-

[1]Average correct recognition of wheat, soybeans, and hay.

[2]Average correct recognition of corn vs. all other types present including crops, woods, and water.

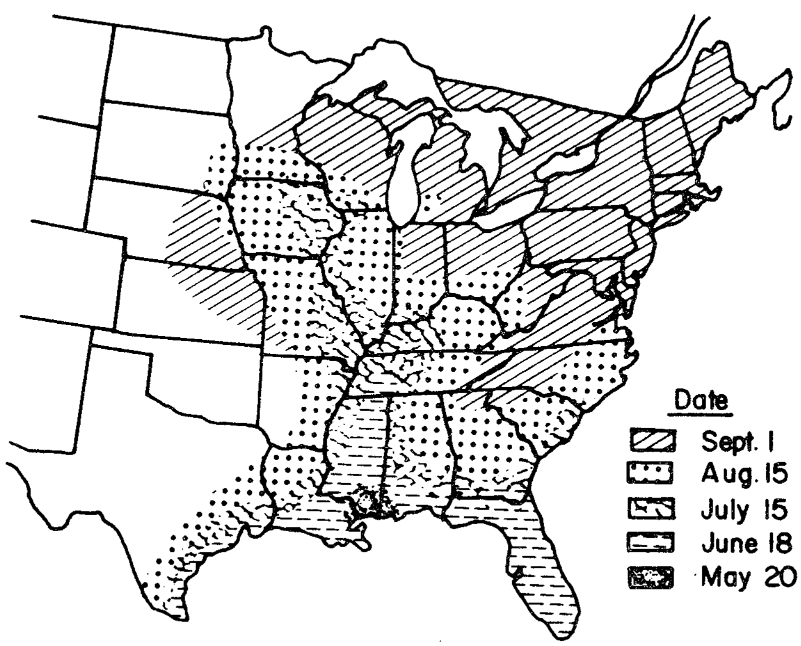


FIGURE 1. IN 1970 SOUTHERN CORN LEAF BLIGHT SPREAD RAPIDLY FROM THE SOUTH TO THE CORN BELT.

FIGURE 2. SOUTHERN CORN LEAF BLIGHT. The disease is characterized by small, brown lesions which increase rapidly in size and number.

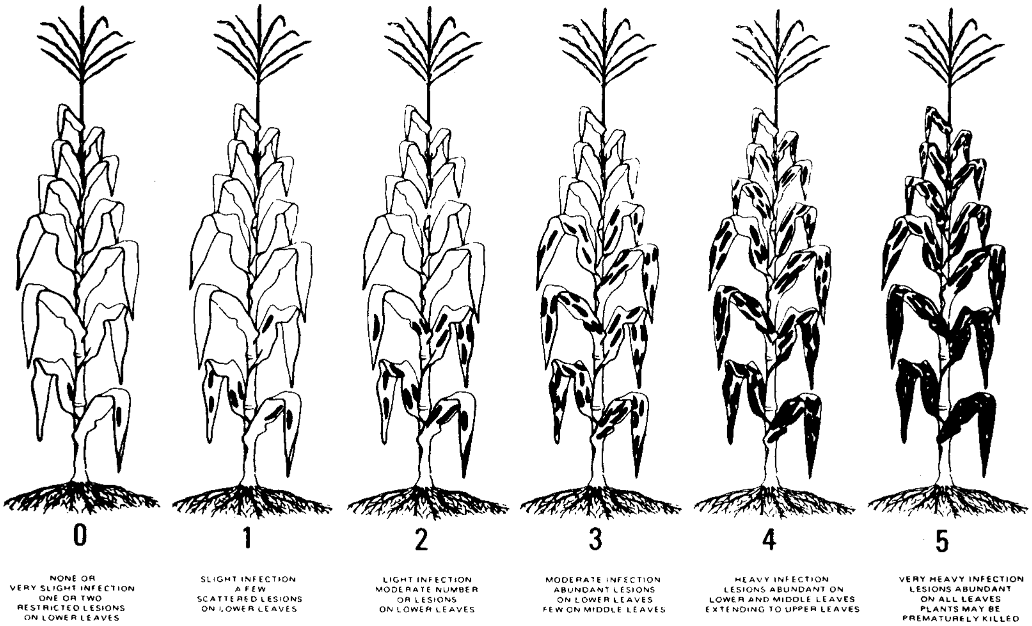


FIGURE 3. SCALE FOR ESTIMATING SOUTHERN CORN LEAF BLIGHT SEVERITY.

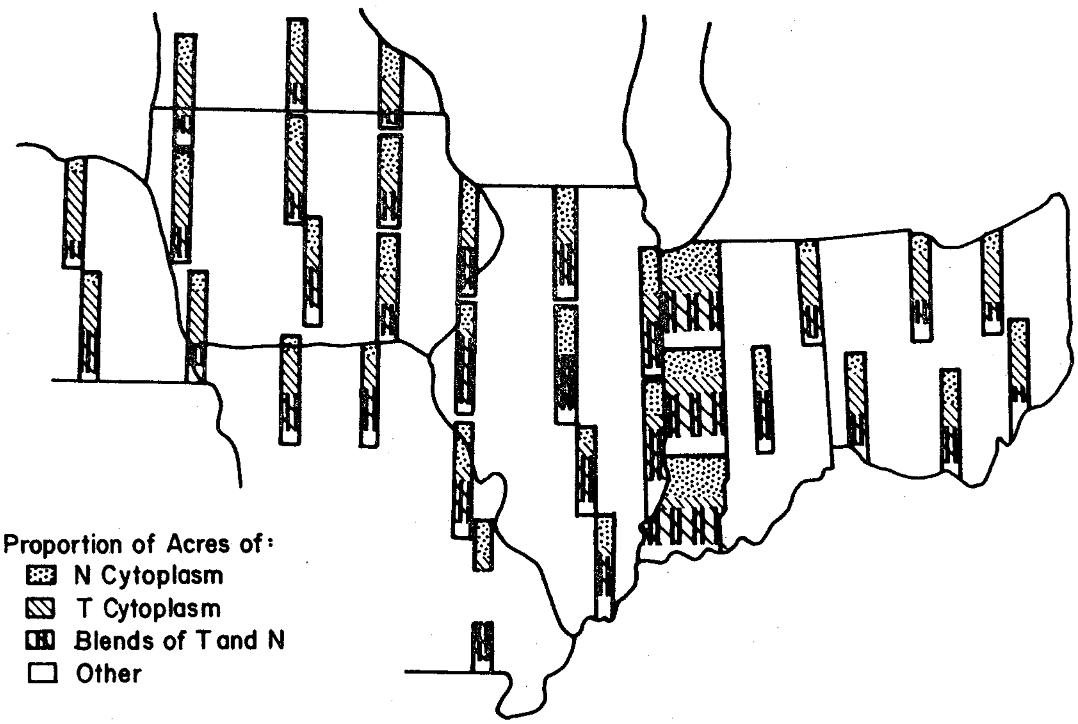


FIGURE 4. DISTRIBUTION OF CORN CYTOPLASM TYPES. The highest propotions of resistant types were planted in the eastern Corn Belt where blight was most severe in 1970.

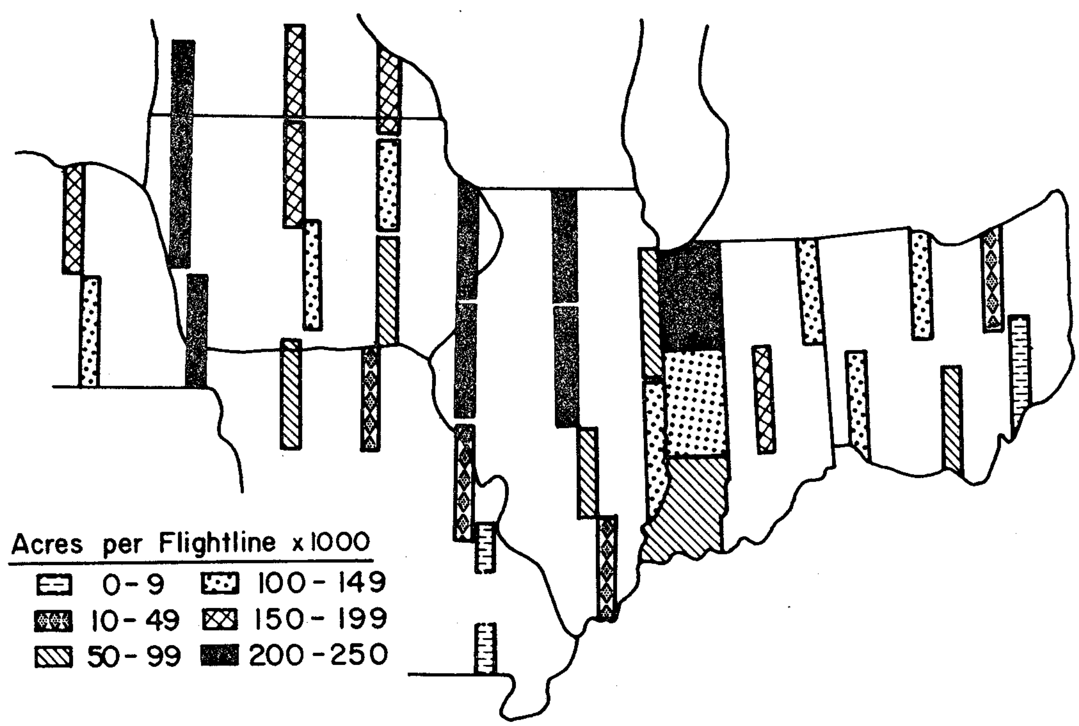


FIGURE 5. DENSITY OF CORN ACRES IN THE EXPERIMENT TEST AREA.

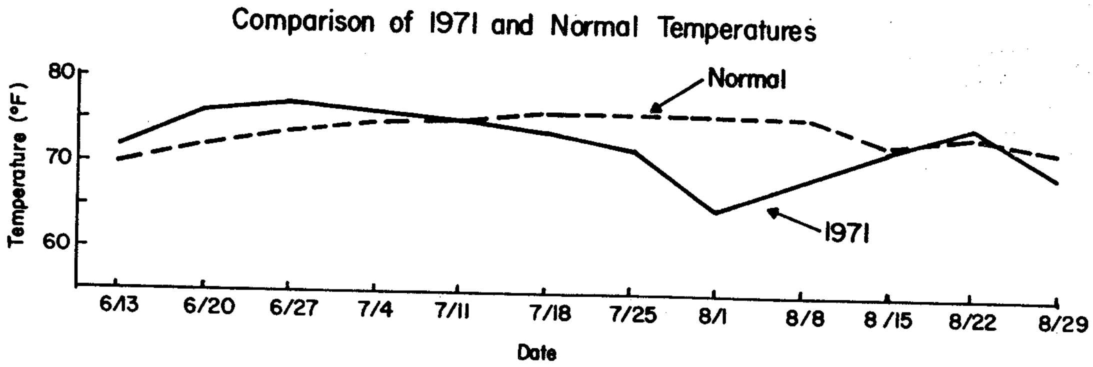


FIGURE 6. COMPARISON OF 1971 AND NORMAL TEMPERATURES. Above-normal temperatures in June and early July were nearly ideal for corn growth. Below-normal temperatures from mid-July to mid-August greatly retarded further blight development and were favorable for high corn yields.

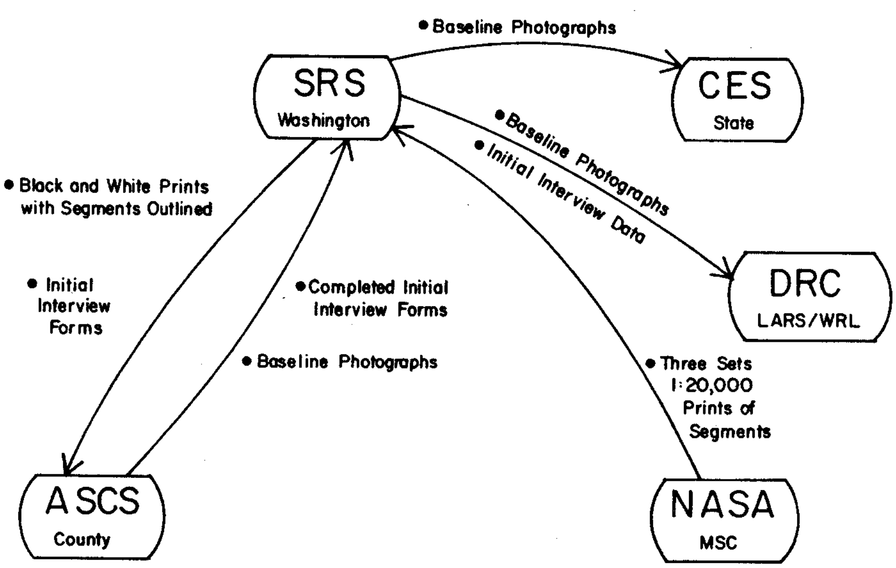


FIGURE 7. PHASE I DATA FLOW. During this phase baseline photography and initial interview data were obtained for use in later phases of the Experiment.

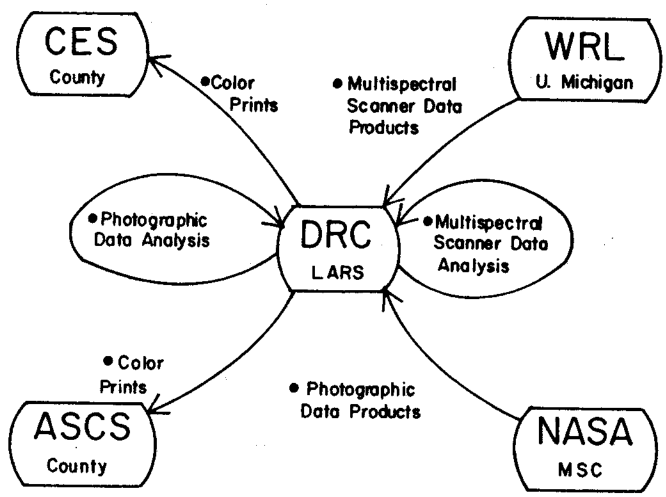


FIGURE 8. PHASE II DATA FLOW. This phase of the Corn Blight Watch was to collect data and perform analyses to determine soils background information for the corn fields.

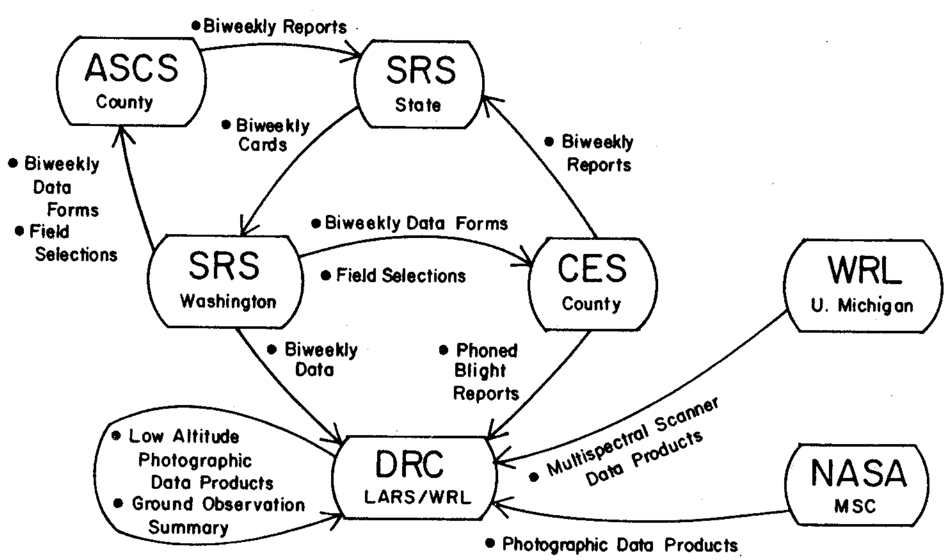


FIGURE 9. DATA ACQUISTION FOR PHASE III. The principal data products were field observation data, photographic data, and multispectral scanner data.

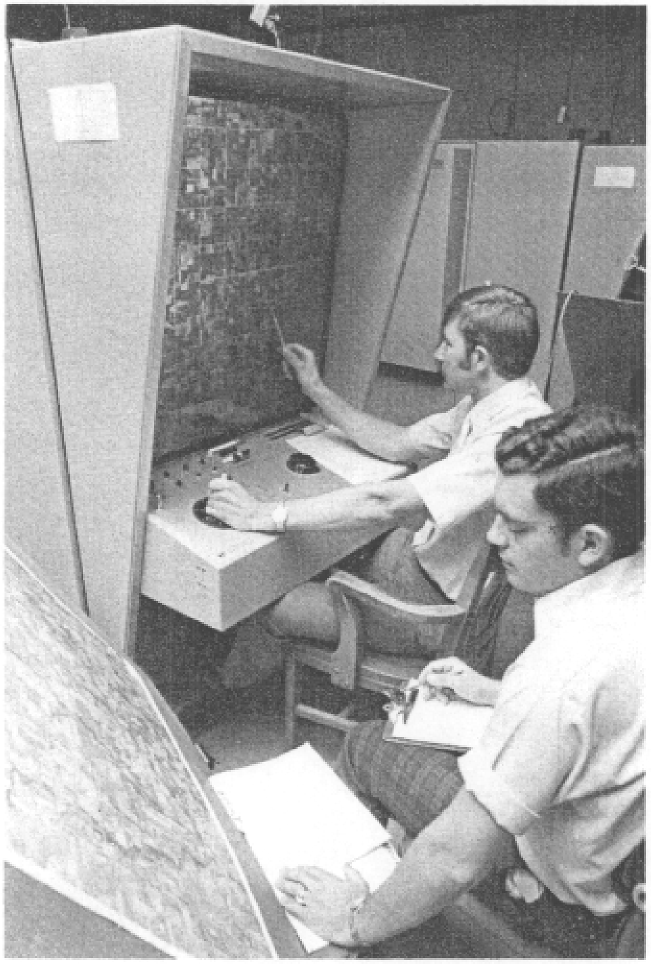


FIGURE 10. INTERPRETATION OF SMALL-SCALE COLOR INFRARED PHOTOGRAPHY USING A VARISCAN REAR-PROJECTION FILM VIEWER.

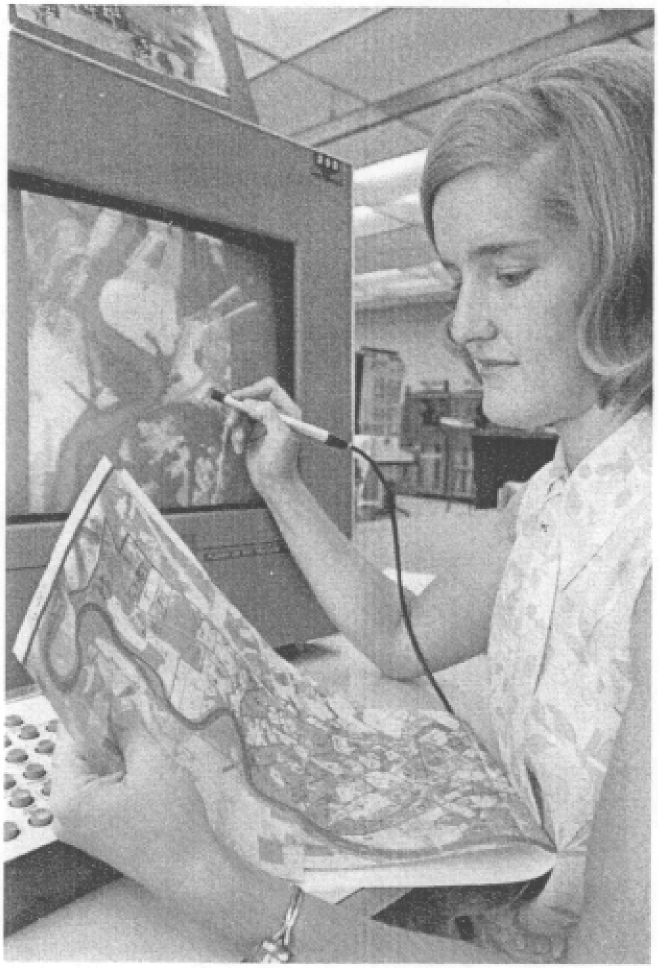


FIGURE 11. DIGITAL DISPLAY USED AT LARS TO LOCATE AND IDENTIFY TRAINING FIELDS IN THE MULTISPECTRAL SCANNER DATA.

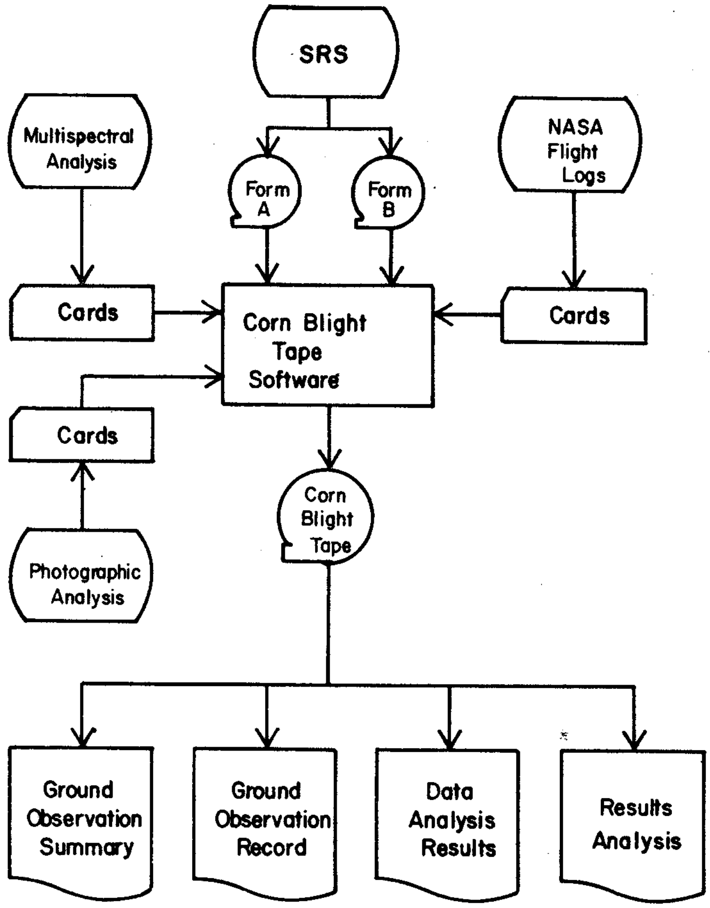


FIGURE 12. ALL GROUND DATA, FLIGHT LOGS, AND ANALYSIS RESULTS WERE STORED ON MAGNETIC TAPE. These merged data were used to analyze and report results of the 1971 Corn Blight Watch Experiment.

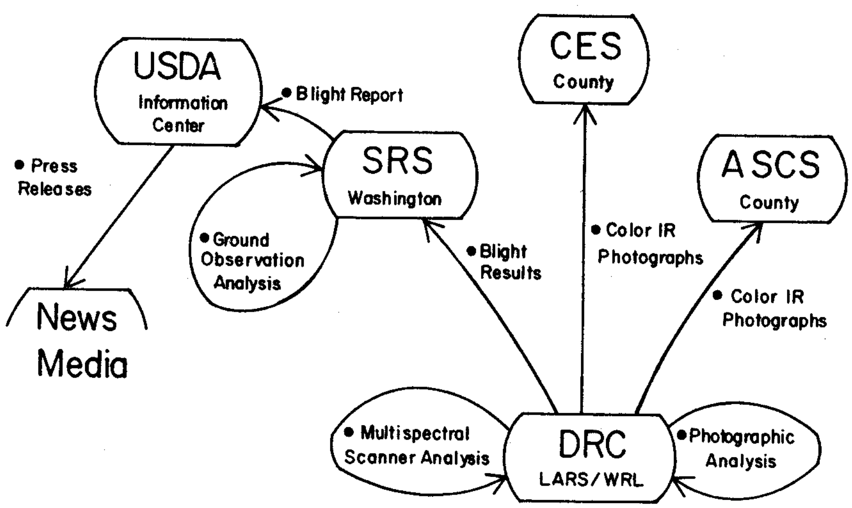


FIGURE 13. RESULTS DISSEMINATION FOR PHASE III. This phase of the Experiment included reporting results to the public.

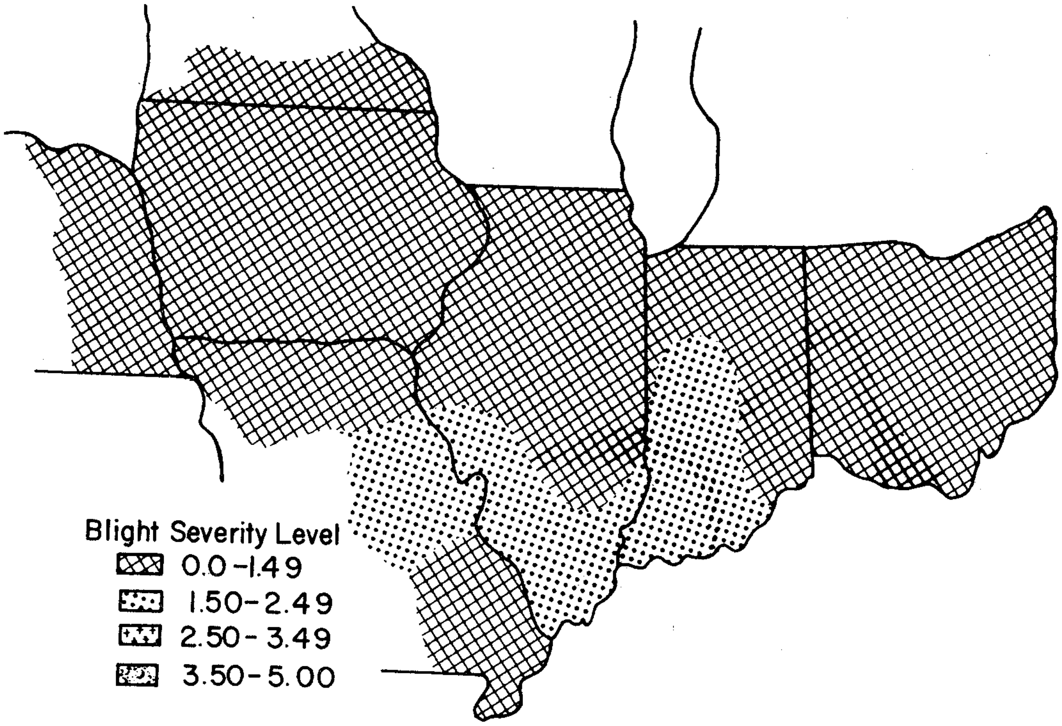


FIGURE 14. BLIGHT SEVERITY OF TEXAS MALE STERILE CYTOPLASM CORN, JULY 26-30, 1971.

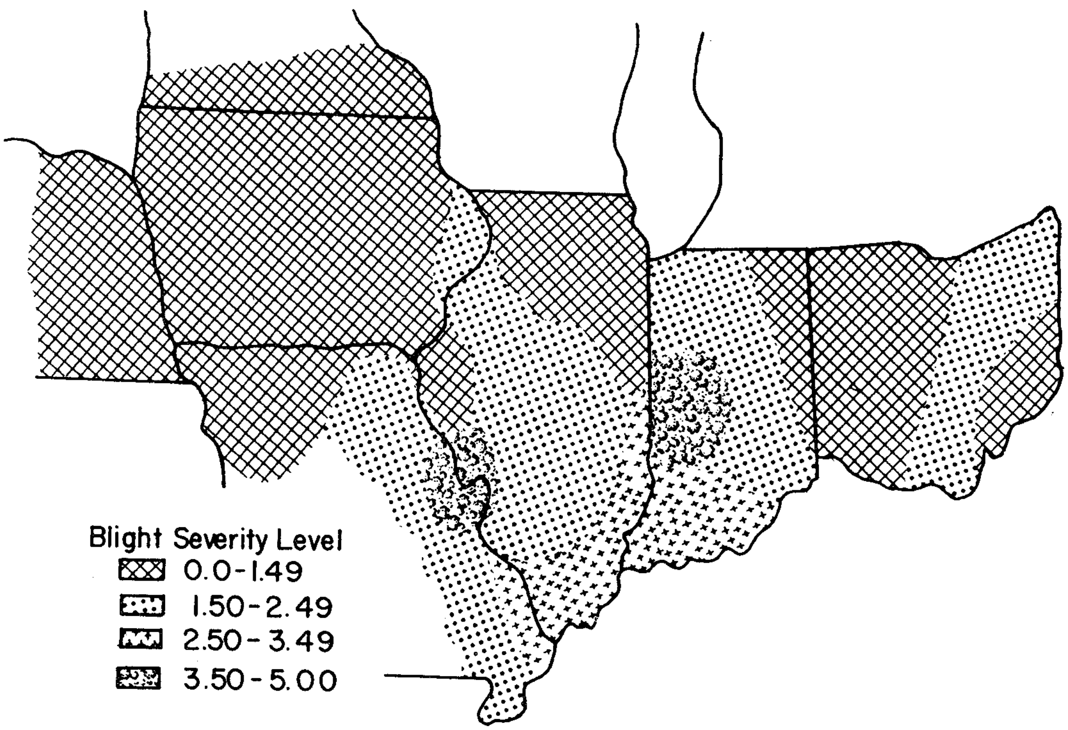


FIGURE 15. BLIGHT SEVERITY OF TEXAS MALE STERILE CYTOPLASM CORN, AUGUST 9-13, 1971.

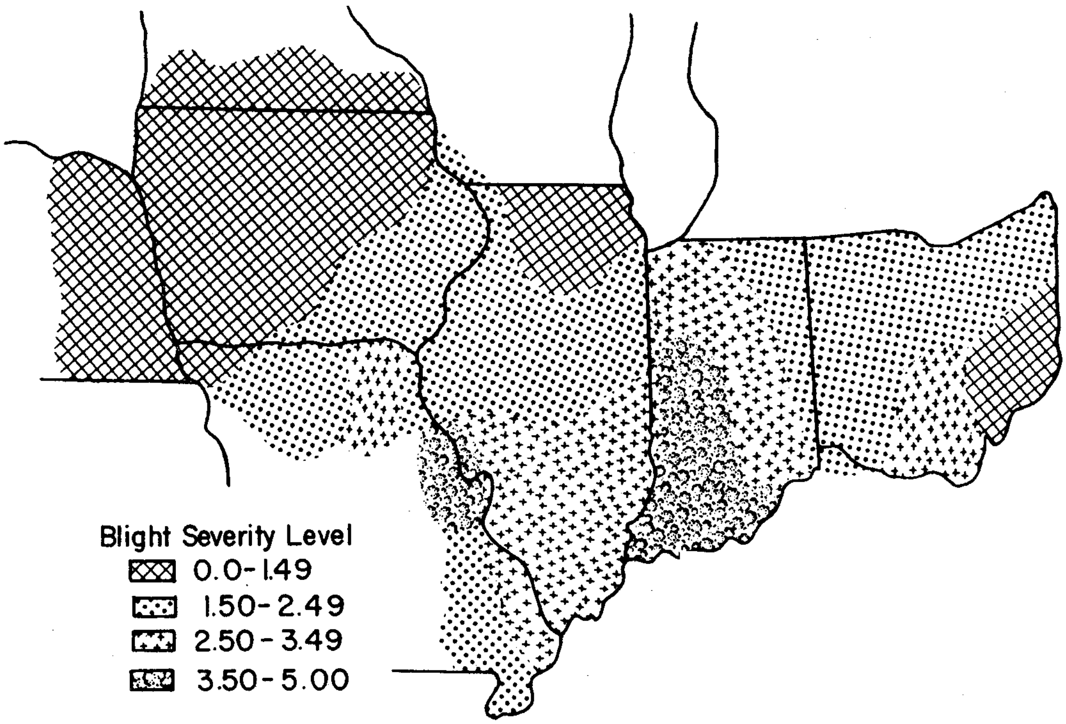


FIGURE 16. BLIGHT SEVERITY OF TEXAS MALE STERILE CYTOPLASM CORN, AUGUST 23-27, 1971.

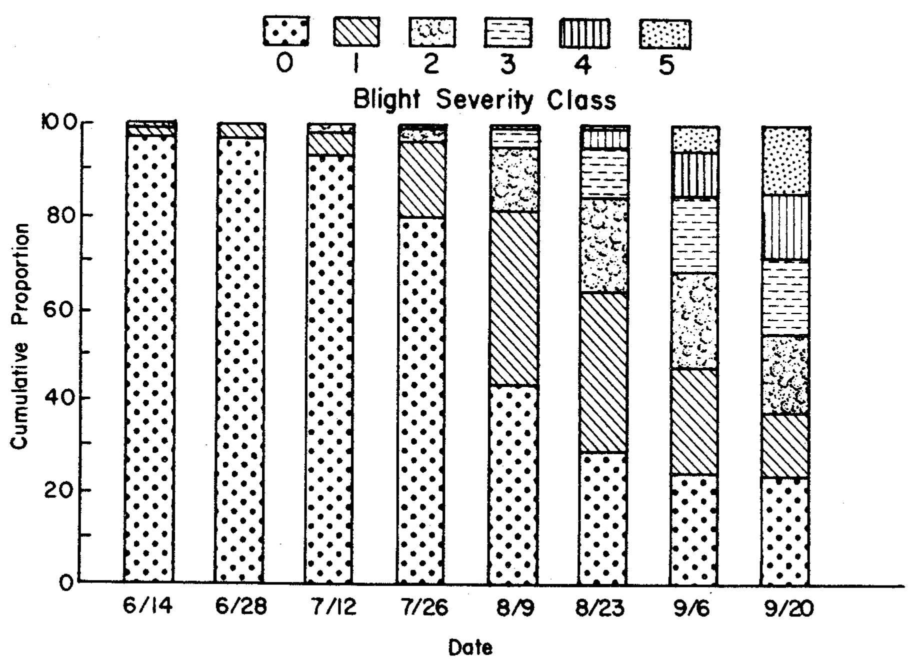


FIGURE 17. DEVELOPMENT OF BLIGHT OVER TIME IN THE CORN BELT AREA.

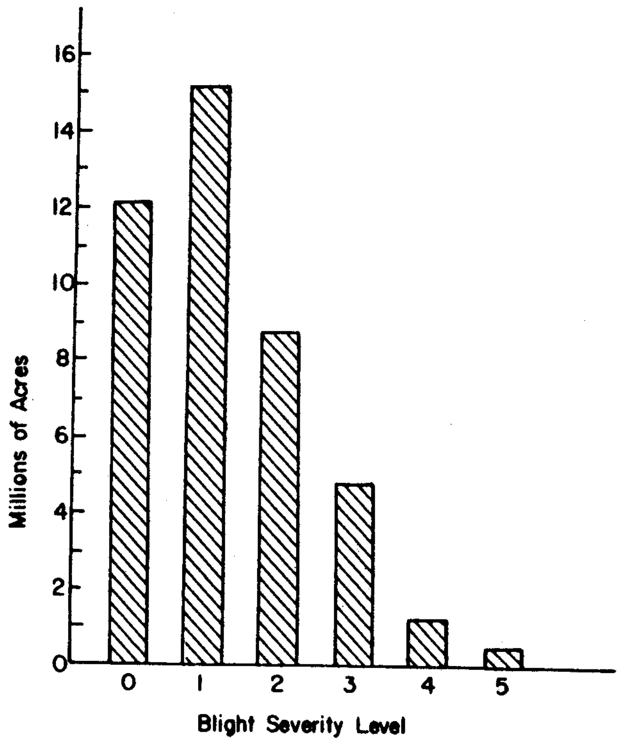


FIGURE 18. NUMBER OF ACRES IN EACH BLIGHT SEVERITY CLASS IN THE CORN BELT, AUGUST 23-27. At this time the crop was nearing maturity and further blight development had little effect on yields

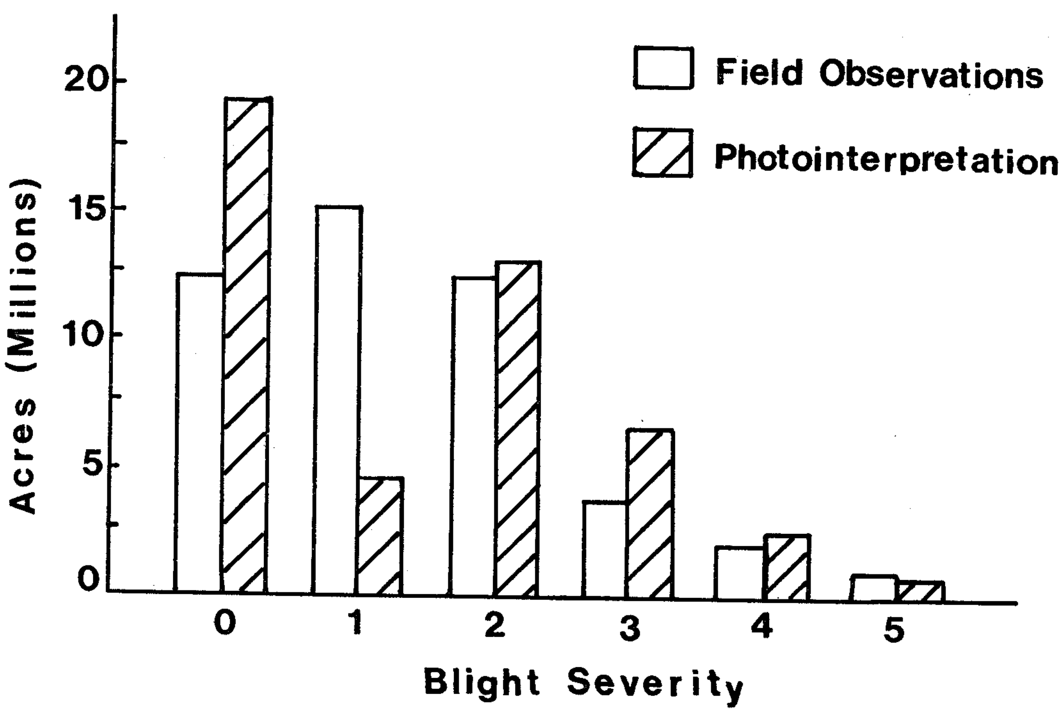
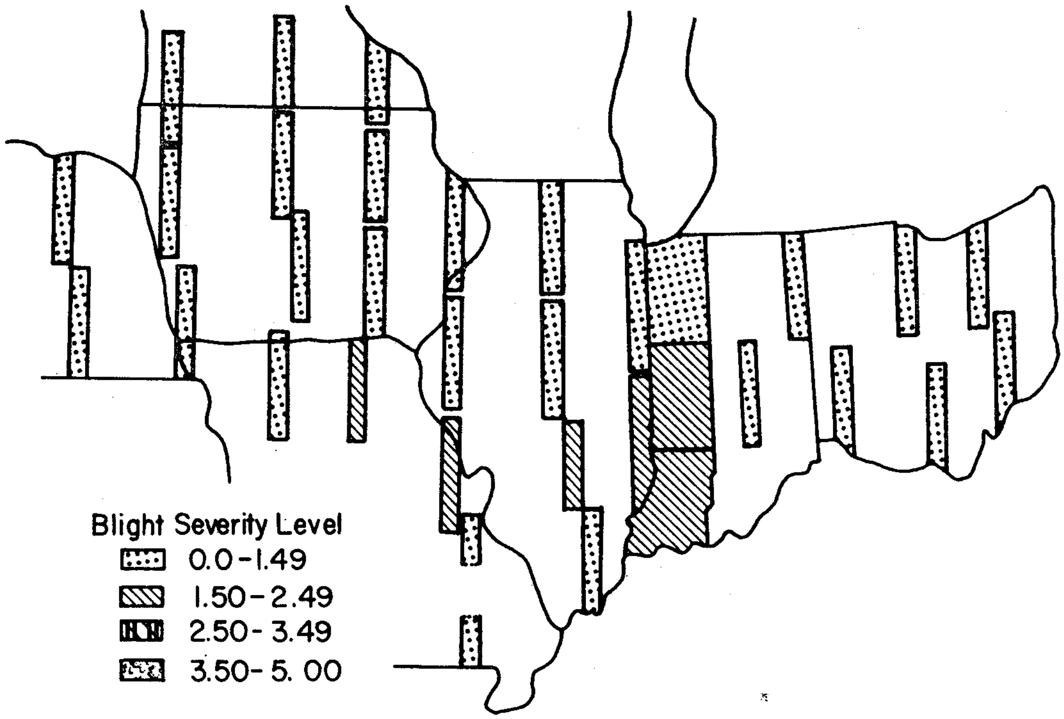


FIGURE 19. COMPARISON OF FIELD OBSERVATION AND PHOTOINTERPRETATION ESTIMATES OF CORN ACREAGES IN INDIVIDUAL BLIGHT CLASSES FOR THE CORN BELT AREA, AUGUST 23 TO SEPTEMBER 5.



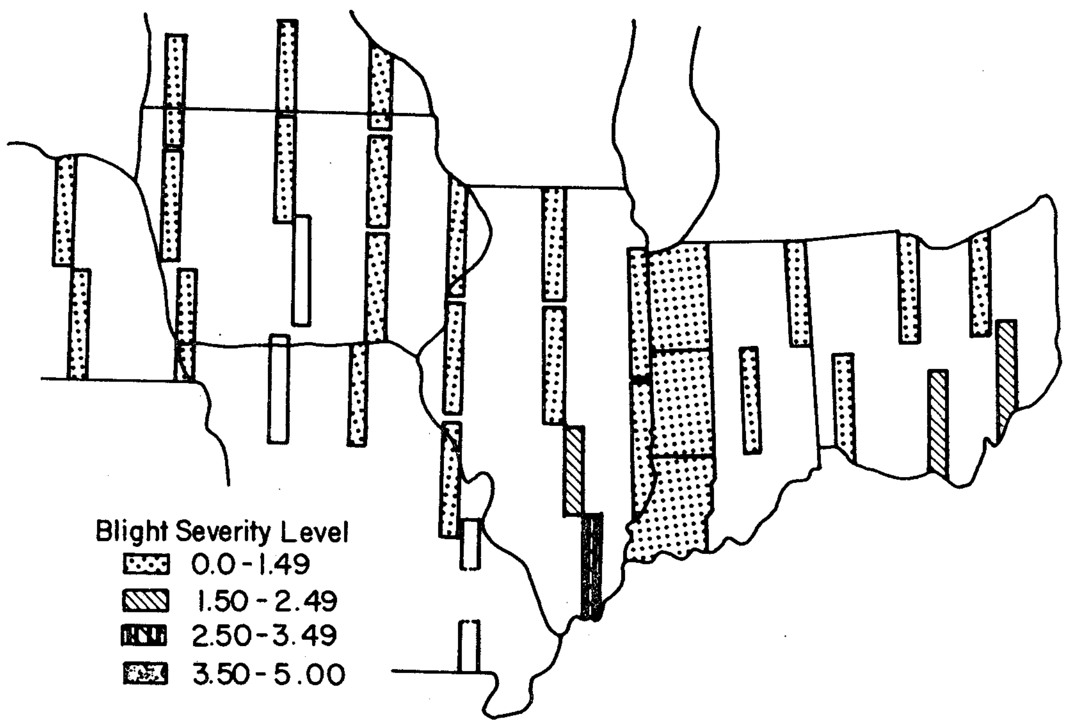


FIGURE 20. AVERAGE BLIGHT SEVERITY LEVELS BY FLIGHTLINE FOR FIELD OBSERVATIONS (TOP) AND PHOTOINTERPRETATION (BOTTOM) FOR THE PERIOD BEGINNING AUGUST 9, 1971.

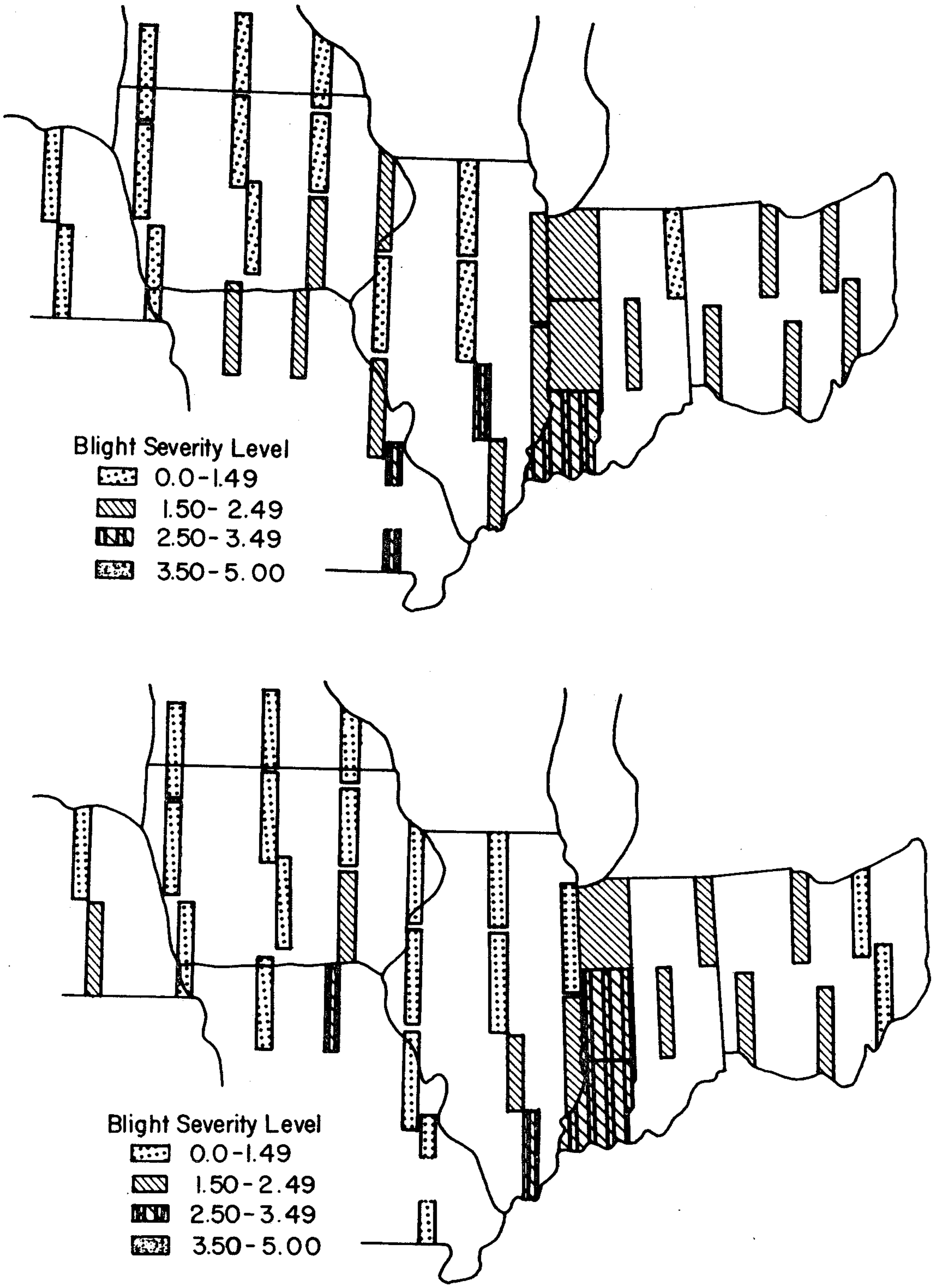


FIGURE 21. AVERAGE BLIGHT SEVERITY LEVELS BY FLIGHTLINE FOR FIELD OBSERVATIONS (TOP) AND PHOTOINTERPRETATION (BOTTOM) FOR THE PERIOD BEGINNING AUGUST 23, 1971.

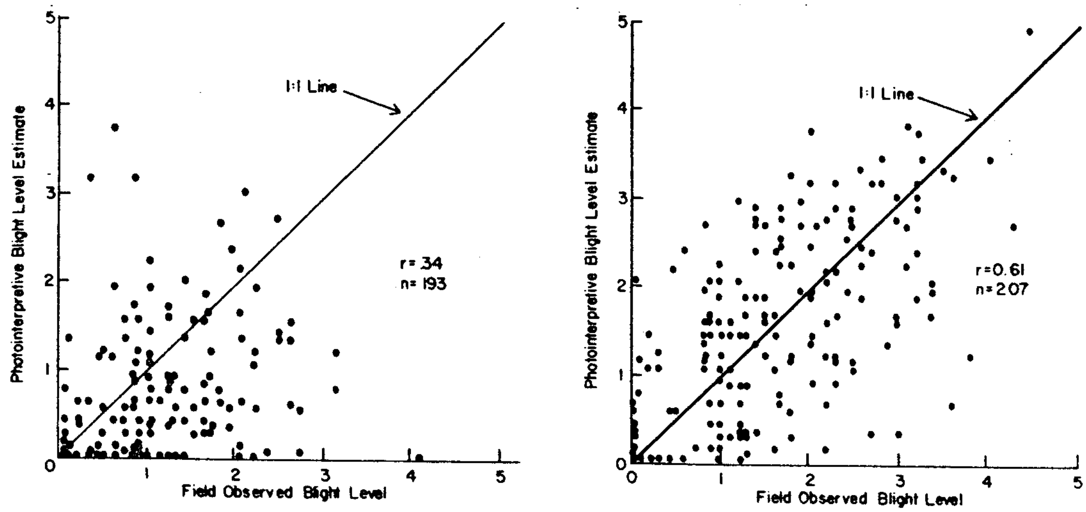


FIGURE 22. CORRELATION OF FIELD OBSERVATION AND PHOTOINTERPRETATION ESTIMATES. The data are segment averages of blight severity for the periods beginning August 9 (left) and August 23 (right), 1971.

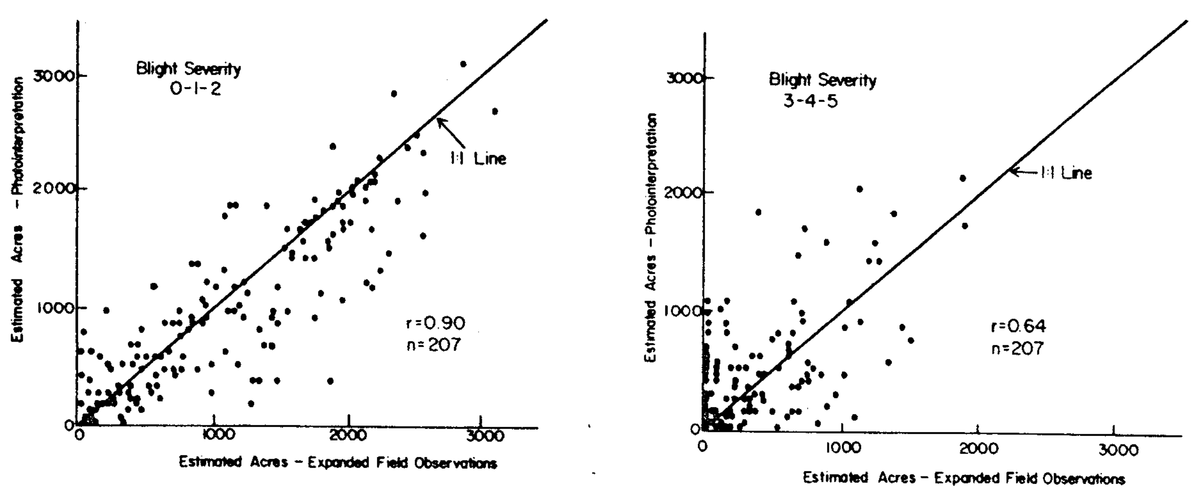


FIGURE 23. CORRELATION OF FIELD OBSERVATION AND PHOTOINTERPRETATION ESTIMATES OF SEGMENT ACREAGES OF HEALTHY (BLIGHT LEVEL 0-1-2) AND BLIGHTED (3-4-5) CORN, AUGUST 23 TO SEPTEMBER 5, 1971.

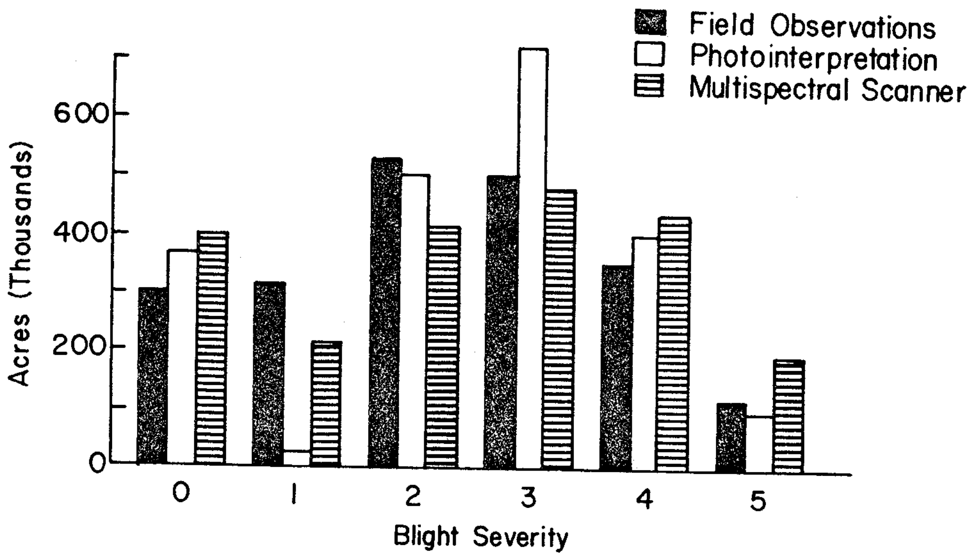


FIGURE 24. COMPARISON OF FIELD OBSERVATION, PHOTOINTERPRETATION AND MACHINE ANALYSIS ESTIMATES OF CORN ACREAGE IN INDIVIDUAL BLIGHT CLASSES FOR THE INTENSIVE STUDY AREA, AUGUST 23 TO SEPTEMBER 5.

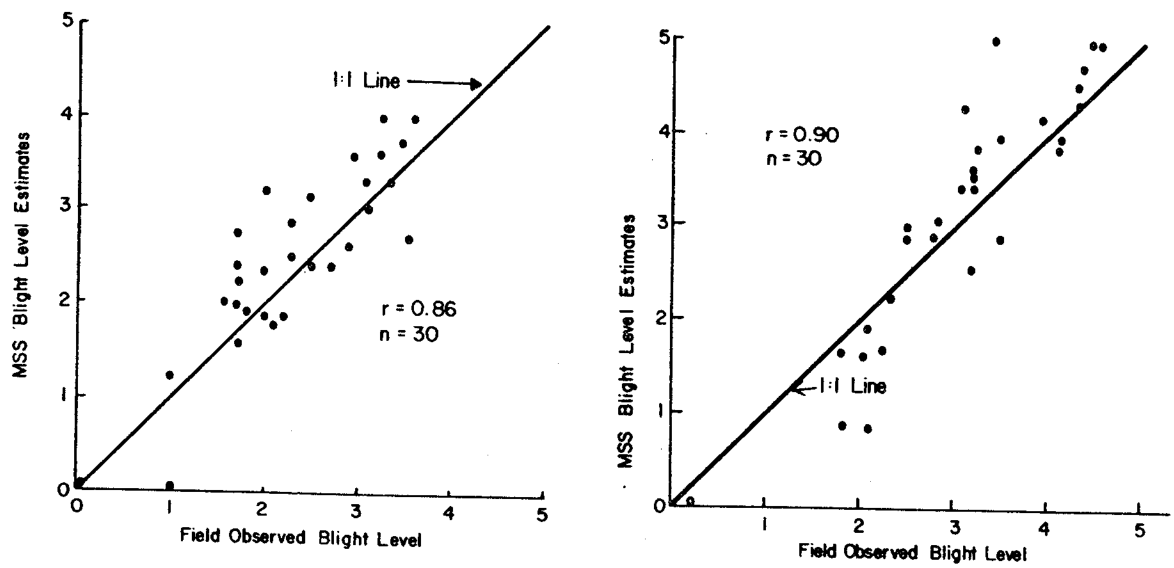


FIGURE 25. CORRELATION OF FIELD OBSERVATION AND MACHINE ASSISTED ANALYSIS OF MULTISPECTRAL SCANNER DATA ESTIMATES OF SEGMENT AVERAGE BLIGHT SEVERITY LEVELS, AUGUST 23 (LEFT) AND SEPTEMBER 6 (RIGHT).

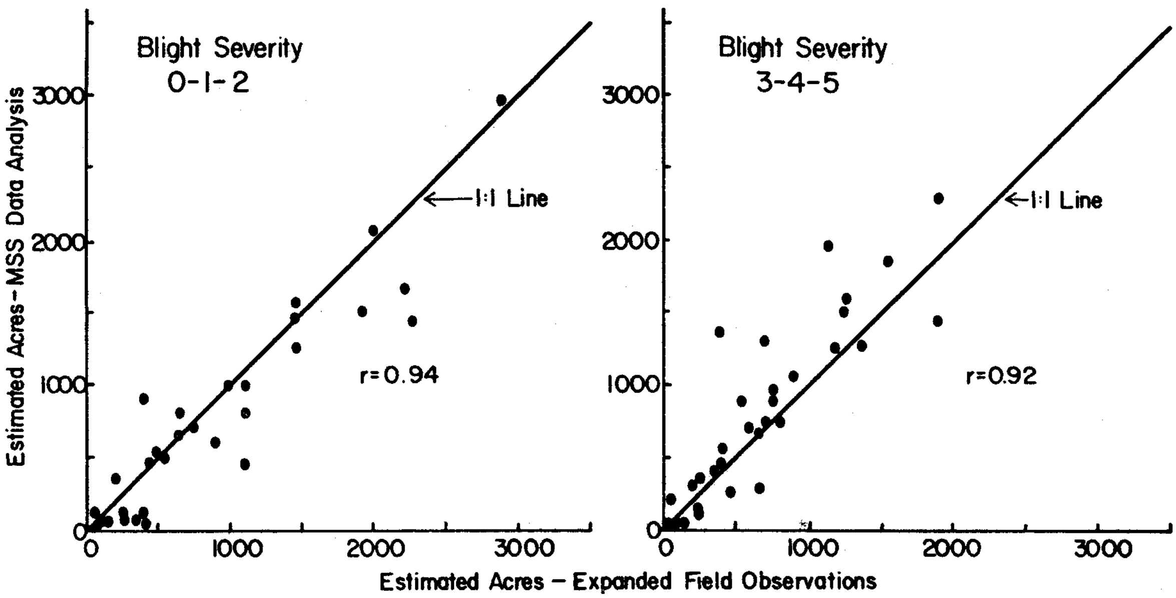


FIGURE 26. CORRELATION OF ESTIMATES FROM MULTISPECTRAL SCANNER DATA AND FIELD OBSERVATIONS OF ACREAGES OF HEALTHY (BLIGHT LEVELS 0-1-2) AND BLIGHTED (3-4-5) CORN IN THE INTENSIVE STUDY AREA SEGMENTS FOR THE PERIOD BEGINNING AUGUST 23, 1971.