NASA SP-353

CORN BLIGHT WATCH EXPERIMENT

SUMMARY REPORT

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

COVER

Remote-sensing aircraft gather corn blight data with film cameras and a multispectral scanner while field observers record data at selected locations. Skilled photoanalysts and computer specialists then interpret the broad, remote-sensor coverage using the field observations to support their findings.

The color infrared images are photographs of the same corn fields in Indiana taken on the dates shown. Changes evidenced in the photographs were used to study the condition of crops at this location during the 1971 growing season. Specifically, the field shaped like a number 7 was used as part of the analysis discussed in the text.

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SUMMARY REPORT

PREPARED BY

EARTH RESOURCES PROGRAM
LYNDON B. JOHNSON SPACE CENTER

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Introduction

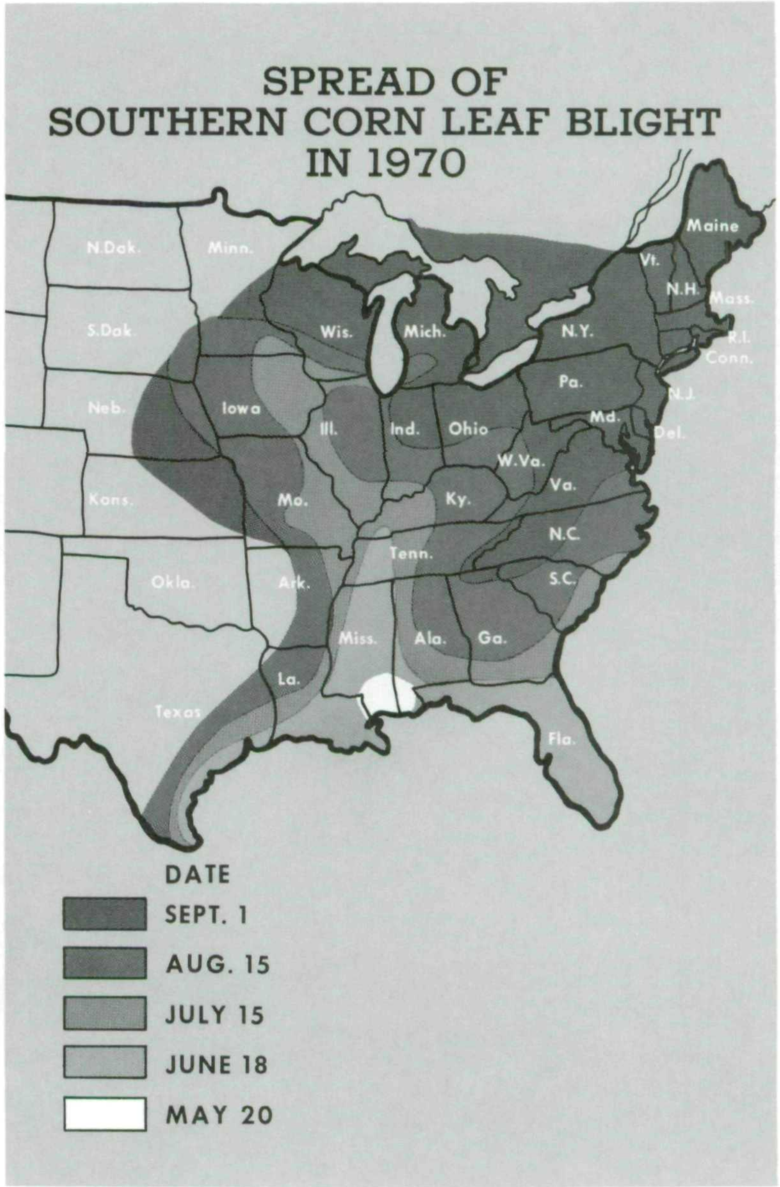
This booklet is addressed to the many participants in the 1971 Corn Blight Experiment and to others interested in remote sensing. It briefly discusses the corn blight problem, how the experiment was organized and conducted, the effect of the blight on the 1971 crop, and some conclusions that may be drawn as a result of the experiment. The information is based on preliminary reports of the Corn Blight Watch Steering Committee and incorporates much illustrative material conceived at Purdue University. A three-volume final report on the Corn Blight Watch Experiment is also being published by NASA on behalf of the steering committee.

1970 PROGRAM

The threat of southern corn leaf blight (SCLB) came as no surprise in 1971. It had caused widespread crop damage the previous year, starting in the Southern States and spreading throughout the Corn Belt. The predicted yield for corn in 1970 was 4.82 billion bushels, but the devastating SCLB fungus (Helminthosporium maydis) ruined 15 percent of the crop. Indiana alone suffered a loss of 95 million bushels.

Agricultural specialists anticipated that SCLB spores would survive the winter to attack susceptible varieties of corn again in 1971. Recognizing the gravity of the situation, the U.S. Department of Agriculture (USDA), with support from the National Aeronautics and Space Administration (NASA), began to investigate the feasibility of using remote-sensing techniques to monitor the spread of SCLB. Late in the summer of 1970, scientific groups from USDA, NASA, Purdue University, and the University of Michigan gathered to discuss the problem and to design a remote-sensing experiment to monitor the corn crop. The first step was to test the potential of remote sensors for detecting SCLB.

For several years, the University of Michigan and Purdue have conducted agricultural remote-sensing experiments with a multispectral scanner. By the summer of 1970, both universities had developed computer systems to analyze multispectral scanner data automatically. There had also been numerous applications of color infrared photography throughout the nation in assessing the vigor of vegetation. Expecting that remote sensing of SCLB would be amenable to these techniques, the investigators sent aircraft over blighted corn fields in central Indiana to test their effectiveness. Results were promising. It appeared that both the multispectral scanner and the cameras with color infrared film could detect several levels of blight severity. The cooperating agencies then began to make arrangements for the 1971 Corn Blight Watch Experiment, the most extensive application of remote sensing by rapid aerial reconnaissance ever undertaken in agriculture.



HOW SCLB ATTACKS THE CORN PLANT

Those designing the experiment needed to know as much as possible about the characteristics of SCLB. Plant pathologists had found that the disease is caused by a fungus propagated by windblown spores. Under warm, moist conditions, the fungus rapidly attacks the leaves of susceptible varieties of corn. The lower, damper leaves of the corn plant canopy are usually the first to be affected.

Significantly, only strains of corn with Texas male sterile (T) cytoplasm (a genetic characteristic that eliminates the need for detasseling in hybrid seed production) are highly susceptible to SCLB; corn with normal cytoplasm is resistant to the fungus. Approximately 85 percent of the corn planted in 1970 was of susceptible varieties.

The first symptom of the disease is the appearance of small, spindle-shaped lesions on the lower leaves. The lesions spread to cover and kill the leaves, moving progressively up the leaf canopy until the entire plant is affected. Low levels of blight infection do not severely influence production of grain; however, in the more severe levels, the grain, if produced, is chaffy and light. Yields are also reduced by secondary infections associated with SCLB, such as ear and stalk rot.

Until the relationship between plant maturity, blight severity, and yield was more fully understood, it was not possible to establish the effects of different levels of blight at different maturity stages. Remote-sensing investigators, therefore, designed their experiments to detect some six levels of infection that they were confident included all significant levels.

Light

Moderate

Severe

Stages of southern corn leaf blight.

ORGANIZING THE EXPERIMENT

The Corn Blight Watch Experiment was formally initiated in April 1971 by the USDA. The experiment was supported by NASA with the cooperation of Purdue University, the University of Michigan, the U.S. Air Force, and agricultural agencies of the seven states in the experimental region. The purpose of the experiment was to evaluate the use of advanced remote-sensing techniques and concepts to:

- Detect the development and spread of corn blight during the growing season across the Corn Belt region
- Assess different levels of infection present in the Corn Belt
- Amplify information acquired by ground visits to better assess current blight status and the probable impact on crop production
- Estimate through extrapolation the applicability of these techniques to similar situations occurring in the future

DEVELOPMENT OF SAMPLING PLAN

The Statistical Reporting Service (SRS) of the USDA developed a sampling plan to allow inferences to be made from remote-sensor data and supporting field observations. Each 1- by 8-mile sample segment over the seven states covered by the remote-sensing experiment was selected to be representative of similar segments in the entire region. Large portions of nonagricultural land were excluded before selection of the test segments. Such areas as cities, lakes, industrial areas, and large rivers were avoided.

The SRS statisticians selected six to 10 representative corn fields in each test segment to be visited by ground observers in conjunction with each remote-sensor overflight. With this ground verification, the remote-sensor data could be interpreted for all the test segments and could be extrapolated to reflect crop conditions over the entire seven-state region.

THE TEST AREA

The 210 representative segments within the seven-state Corn Belt region included approximately 1806 corn fields along 30 flight lines in the states of Ohio, Illinois, Indiana, Missouri, Iowa, Nebraska, and Minnesota. In addition, eight overlapping flight lines were established over an intensive study area in eastern Illinois and western Indiana. The thirty 1- by 10-mile segments in the intensive study area were parallel to the north-south flight lines, while the 180 1- by 8-mile segments in the larger test area were alined east to west, or perpendicular to the flight lines.

FLIGHT LINES IN THE TEST AREA

AIRCRAFT DATA ACQUISITION

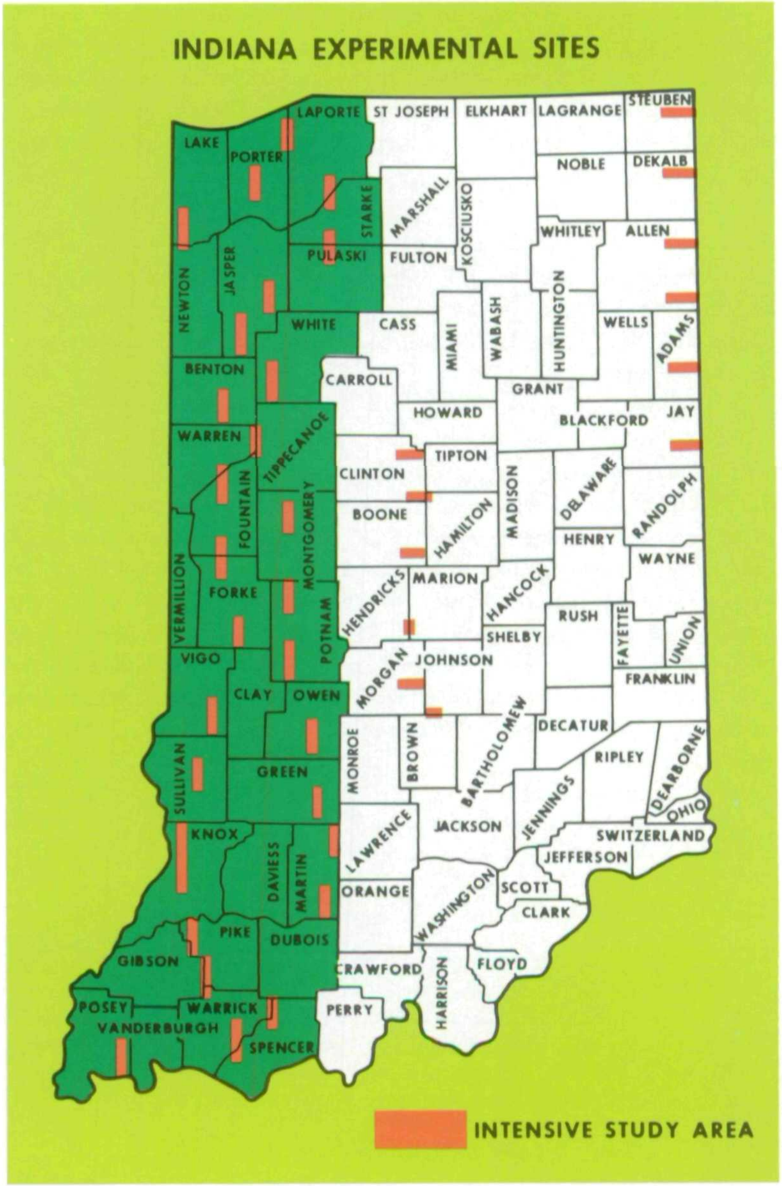
The NASA Johnson Space Center (JSC) made its Earth Survey-3 (ES-3) aircraft available to obtain high-altitude photographs. The ES-3 is a U.S. Air Force RB-57F adapted to carry a special package of remote sensors and assigned to the JSC Earth Observations Aircraft Program Office. In addition, a C-47 aircraft operated by the University of Michigan was made available for multispectral scanner coverage from lower altitudes. The range and altitude of the C-47 was adequate for the intensive study area. It was, however, too limited to cover the entire seven-state area. For the larger area, the RB-57F was the ideal platform. Its 60 000-foot operating altitude, high speed, and long range made it well-suited to cover the flight lines of the seven-state experimental area on a timely basis. The principal sensors used on the RB-57F were RC-8 cameras.

For the initial land-use baseline photographs, the cameras were loaded with black-and-white film. However, for actually detecting SCLB, the cameras used color infrared film. Color infrared is very sensitive to plant life. It records vigorous crops as bright red, and unhealthy or dead plants appear light pink to gray. A skillful photointerpreter can recognize several levels of corn blight infection recorded on this film.

Interpretation of the photographs was done by persons with strong agricultural backgrounds assigned to the experiment by USDA, state agricultural experiment stations, and several universities. The interpreters received special training at the Interpretation Center established for the project at the Purdue Laboratory for Applications of Remote Sensing (LARS).

Before the photographs were delivered to the interpreters for analysis, they were screened for quality and indexed for location by NASA contract personnel at JSC. These contract personnel also served in an advisory capacity to the team for photoanalysis at the LARS Interpretation Center throughout the experiment.

The experiment was divided into three sequential phases covering the spring and summer of 1971. Phase I, April 15 to April 30, was devoted to land-use mapping. Phase II, May 10 to May 30, provided information about soil conditions. Phase III, June 14 to October 1, involved actual detection of corn blight by remote sensing.



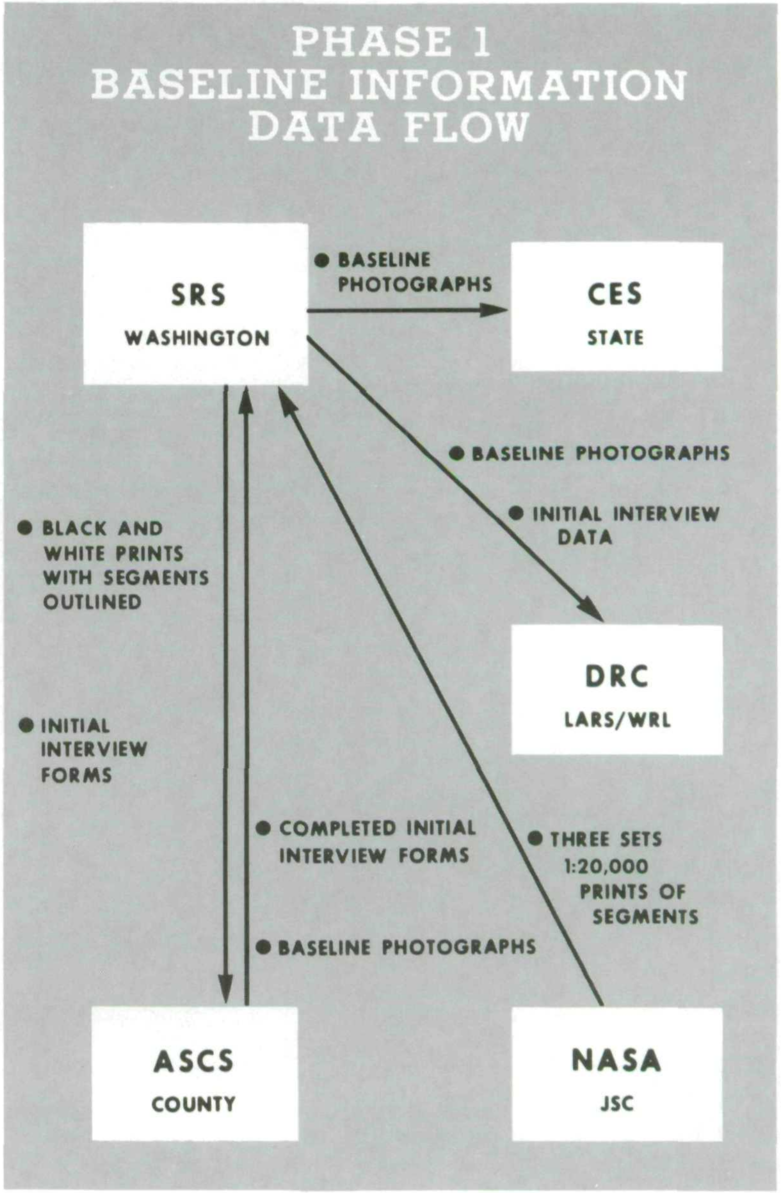
In Phase I, the RB-57F aircraft covered the flight lines at 60 000 feet, obtaining black-and-white photographs to provide an aerial map of the test segments. Concurrently, Agricultural Stabilization and Conservation Service (ASCS) personnel visited the selected corn fields to obtain baseline information to convert the photographs into agricultural crop-use maps.

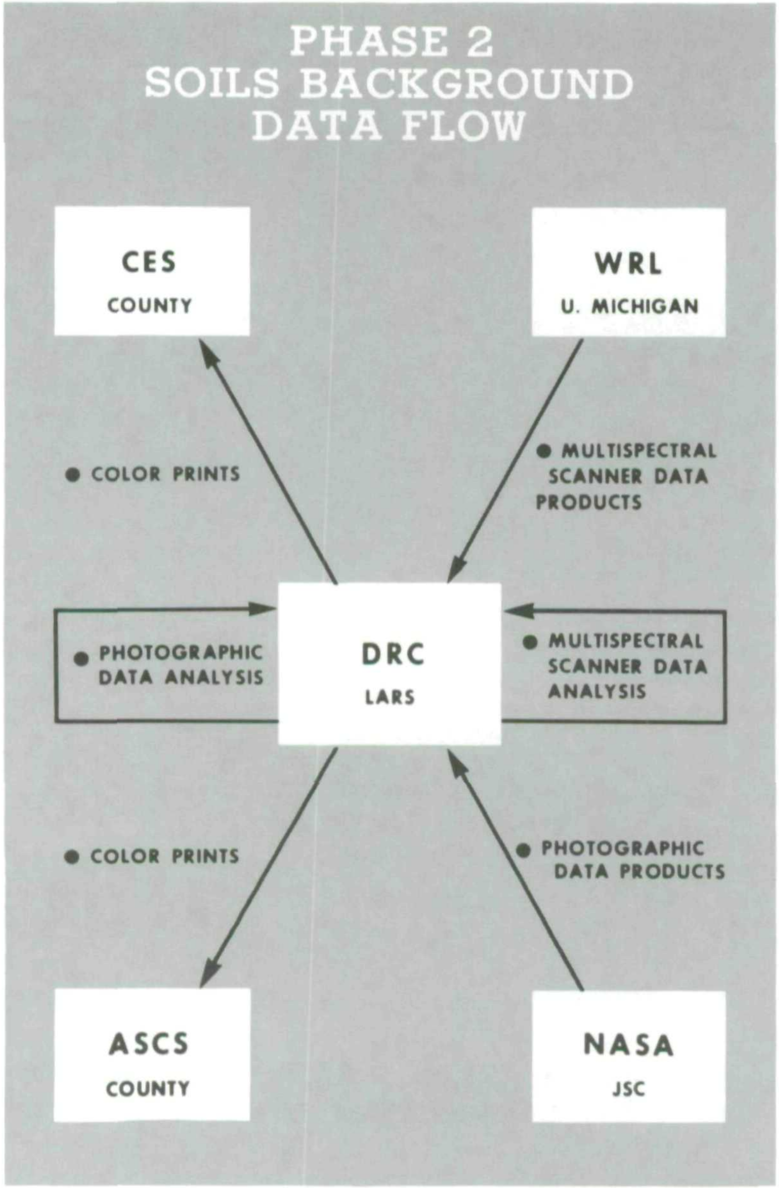
In Phase II, the RB-57F aircraft collected high-altitude, color infrared photographs over all flight lines at 60 000 feet to provide a background for evaluation of soil conditions before the emergence of the corn plants.

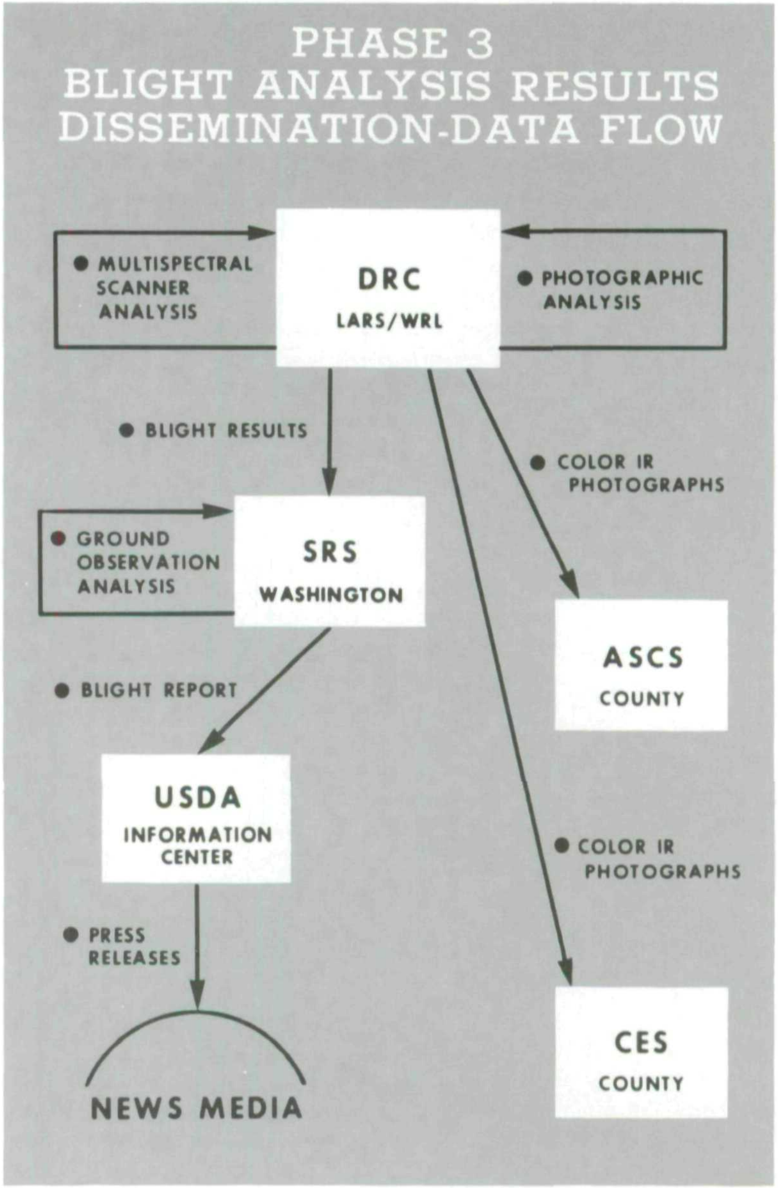
In Phase III, from mid-June through September, both the C-47 and the RB-57F aircraft obtained remote-sensor data over their assigned flight lines every 2 weeks. The RB-57F was flown at 60 000 feet using two RC-8 cameras loaded with false color infrared (2443) film. The University of Michigan C-47 flew the 30 overlapping flight lines of the intensive study area at 5000 feet during each mission period. The Michigan scanner system provides 12 multiband data channels in the 0.3 to 14.0 micrometer wavelength region of the electromagnetic spectrum, registering the properties of the terrain scene in the form of an electrical signal.

LEGEND FOR DATA FLOW CHARTS

ASCS – Agricultural Stabilization and Conservation Service
CES – Cooperative Extension Service
DRC – Data Reduction Complex
LARS – Laboratory for Applications of Remote Sensing (Purdue University)
JSC – Johnson Space Center
NASA – National Aeronautics and Space Administration
SRS – Statistical Reporting Service
WRL – Willow Run Laboratories (University of Michigan)




PHASE 2
SOILS BACKGROUND
DATA FLOW
CES
COUNTY
WRL
U. MICHIGAN
● COLOR PRINTS
● MULTISPECTRAL SCANNER DATA PRODUCTS
● PHOTOGRAPHIC DATA ANALYSIS
DRC
LARS
● MULTISPECTRAL SCANNER DATA ANALYSIS
● COLOR PRINTS
● PHOTOGRAPHIC DATA PRODUCTS
ASCS
COUNTY
NASA
JSC


PHASE 3
BLIGHT ANALYSIS RESULTS
DISSEMINATION-DATA FLOW
● MULTISPECTRAL SCANNER ANALYSIS
DRC
LARS/WRL
● PHOTOGRAPHIC ANALYSIS
● BLIGHT RESULTS
● COLOR IR PHOTOGRAPHS
● GROUND OBSERVATION ANALYSIS
SRS
WASHINGTON
ASCS
COUNTY
● BLIGHT REPORT
USDA
INFORMATION CENTER
● COLOR IR PHOTOGRAPHS
● PRESS RELEASES
NEWS MEDIA
CES
COUNTY

FIELD OBSERVATIONS

In coordination with the remote-sensor overflights, more than 500 enumerators from the ASCS, Agricultural Extension Service (AES), Cooperative Extension Service (CES), and personnel representing the states involved reported field observations from designated sample points. When blight was suspected, leaf samples were collected and analyzed for the occurrence of symptomatic lesions. These data were compiled by the Statistical Reporting Service in Washington, D.C., and sent to the LARS Interpretation Center at Purdue University for incorporation into the blight detection program. These field observations gave the interpreters confirmation regarding blight occurrence as interpreted from remote-sensor data.


Typical color infra-red image used in the experiment.

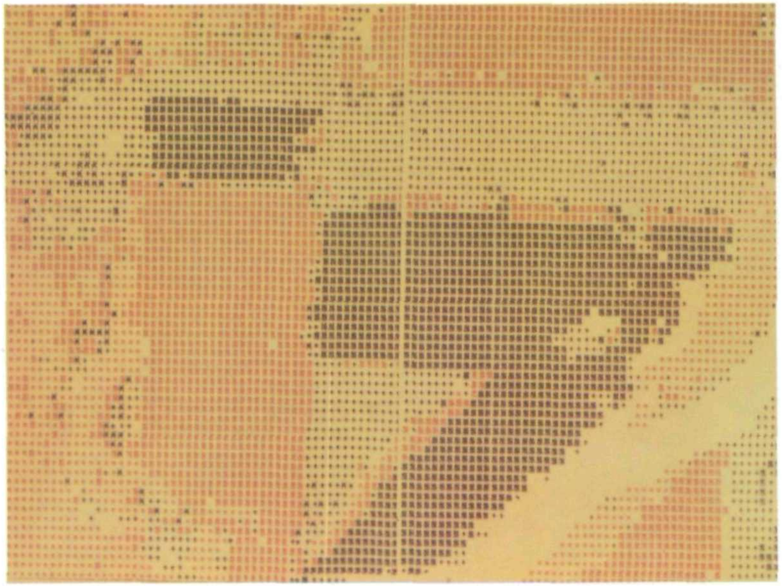
DATA REDUCTION

Film containing the photographic data acquired by the RB-57F was processed at JSC in Houston and delivered to the LARS Interpretation Center at Purdue.

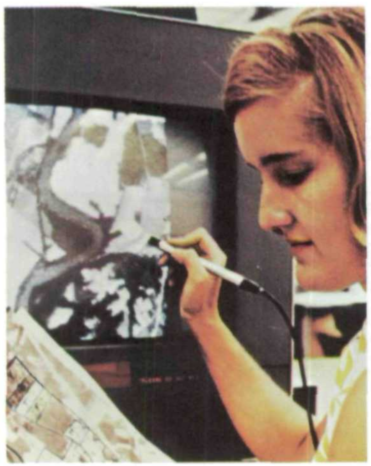
A team of photoanalysts at LARS reduced the biweekly data, classifying the corn of each segment into blight or nonblight categories. Blighted fields were classified by levels of severity and uniformity of the occurrence of blight within the field.

Multispectral scanner data acquired over the intensive study area were analyzed by pattern recognition programs at LARS and at the University of Michigan Institute for Science and Technology (IST). The LARS used a fully digital computer system and IST employed an analog/digital hybrid computer system to identify blighted fields and classify them by levels of blight severity. The results of both the photographic and multispectral scanner analyses were assembled, compared, and evaluated at the LARS Interpretation Center at Purdue University.


Photointerpreter studies color infrared photographs to identify blighted fields.



Computer printout map classifying corn fields by blight level reveals severely blighted area. (Note that this is the same location shown in the sequential photographs on the cover.)



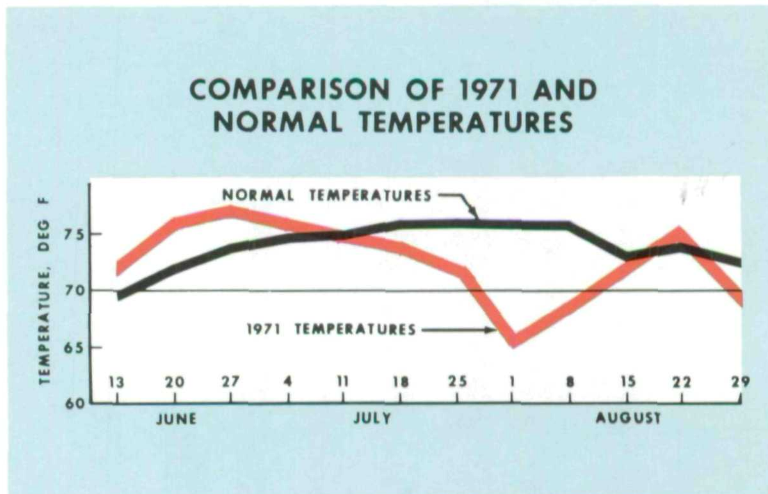
Analyst uses a light pen to outline a training field on a cathode-ray tube (CRT) display. The computer will use data gathered by field observers to compare this field to others on the data tape.

EFFECT OF BLIGHT ON 1971 CROP

The effects of SCLB on corn production were greatly reduced in 1971 because of increased acreage planted in corn, increased use of blight-resistant varieties, early planting, and a timely cool period in mid-July. However, blight occurred throughout the region in the early summer.

Although the levels of severity reported were low, SCLB had been detected in 600 counties by mid-July. Then, about the time of tasseling, came several weeks of cool, dry weather. This unexpected respite from the anticipated warm, humid conditions tended to check the spread of SCLB and to inhibit the severity in plants that had been infected.

The USDA used information from the Corn Blight Watch Experiment to evaluate reports of widespread SCLB. For example, field observations from the Watch showed that very few fields in the sample

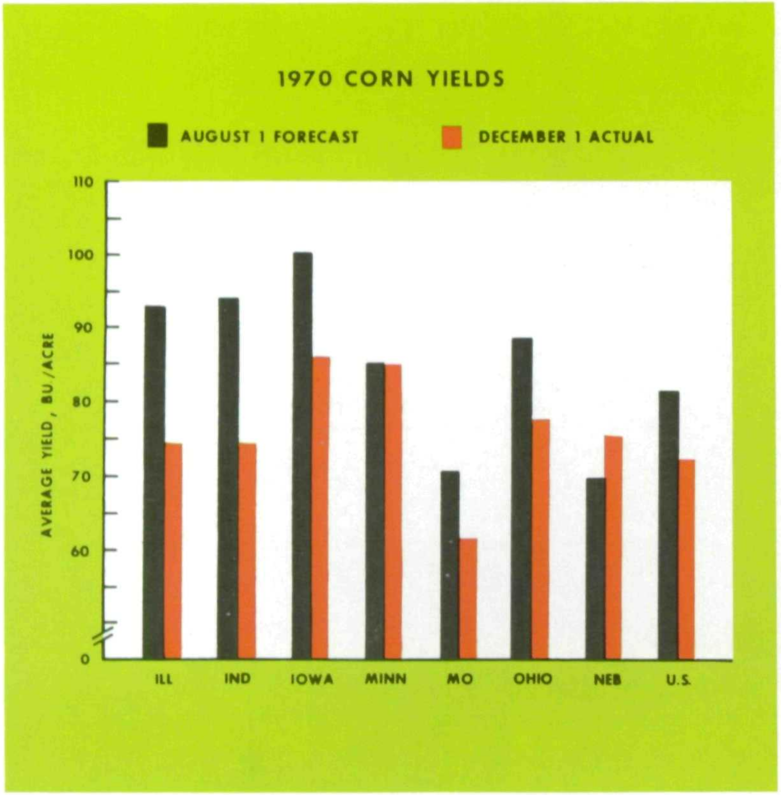


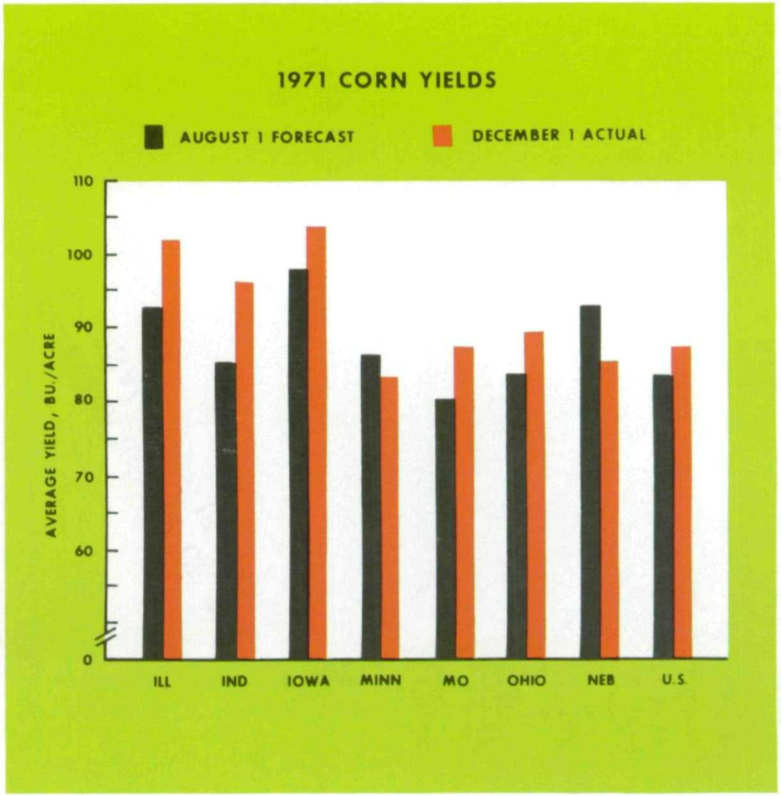
areas had suffered more than mild infections as of late July. Thus, the Corn Blight Watch information was used in 1971 as a tool in evaluating all possible indications. It could not be used as an estimator of production because no parameters relating early blight infections to final production had been developed. Consideration of moderate to severe levels were later found to be important in estimating.

Several weeks before harvest, the preliminary results of the Corn Blight Watch Experiment indicated the absence of conditions that would seriously reduce total corn production. As anticipated, a bumper crop of corn was harvested in 1971.

In several regions where susceptible T-cytoplasm varieties of corn were heavily planted, SCLB significantly reduced yield. Preliminary studies relating yield to level of blight severity and maturity indicate only two or three levels of blight were significant in predicting crop yield. Early in the season, detection of mild degrees of blight was used to trace its extent and spread, but, from the middle to the end of the growing season, only moderate to severe levels of blight were used in estimating corn production for the year.

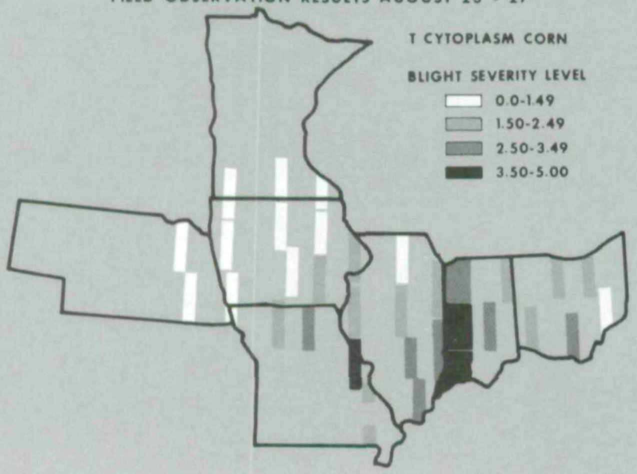
At the end of the 1971 season, corn yields were obtained from sample units in fields that had been observed throughout the summer. These samples were used to establish relationships between levels of infection at different crop maturity stages and yield reductions. The results of these studies are shown in table I.





AVERAGE BLIGHT SEVERITY LEVEL BY FLIGHTLINE

FIELD OBSERVATION RESULTS AUGUST 23 - 27



PROPORTION OF ACRES IN EACH BLIGHT SEVERITY CLASS

FIELD OBSERVATIONS - CORN BELT

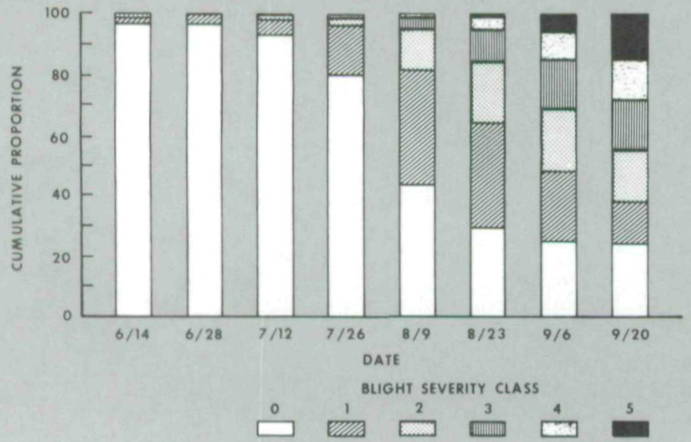


TABLE I. AVERAGE YIELD (BUSHELS/ACRE[a]) AS INFLUENCED BY TIME AND SEVERITY OF BLIGHT INFECTION

Date	Blight severity level					
	0	1	2	3	4	5
	All cytoplasm types[b]					
July 26 to 30	114	114	112	84	69	--
Aug. 9 to 13	115	114	114	104	86	92
Aug. 23 to 27	115	112	117	114	100	77
Sept. 6 to 10	108	113	113	122	115	104
	T-cytoplasm[c]					
July 26 to 30.	100	102	90	76	57	--
Aug. 9 to 13	98	98	106	98	83	81
Aug. 23 to 27	99	94	102	105	92	78
Sept. 6 to 10	100	86	104	104	101	92

[a]Preliminary calculations show coefficients of variation of 5 to 15 percent.

[b]Average yield, 113 bushels/acre.

[c]Average yield, 98 bushels/acre.

PROGRAM SUMMATION

The 1971 Corn Blight Watch Experiment was a highly successful program in many respects. It was an excellent demonstration of the operational capabilities of remote-sensing techniques. Extremely large quantities of data were collected over the seven-state experimental area on a biweekly basis. These data were processed, reduced, evaluated, and reported within these short 2-week cycles.

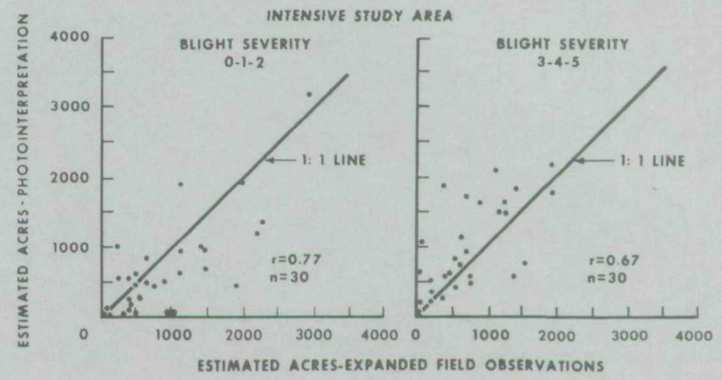
Some of the benefits of the experiment were unexpected. For example, the fact that SCLB was being carefully monitored appeared to dampen corn price fluctuations on the commodity market.

Several conclusions can be drawn from these data.

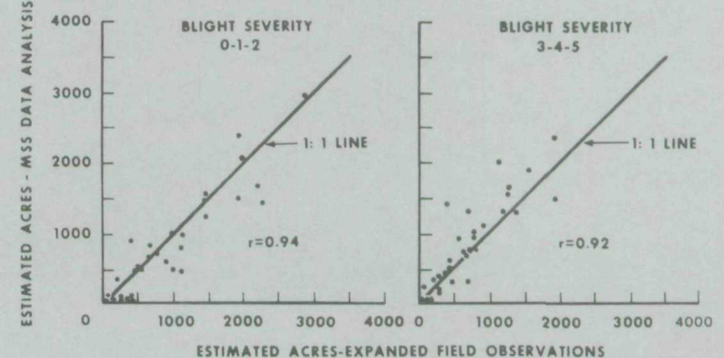
- Yield reduction is related to early season blight infection.
- Slight to moderate blight infection occurring in late August and early September had little (if any) effect on yield.
- The blight levels that significantly affected yields are the same levels that can be detected by remote sensing.

The Corn Blight Watch Experiment was the first time that a sound statistical design was used for a large-scale, remote-sensing program. Accuracy of corn identification by remote sensing exceeded 90 percent throughout the experiment, and the correlation between field observations of blight levels and classification of blight levels using remote-

CORRELATION OF PHOTOINTERPRETATION AND FIELD ESTIMATES OF ACRES IN GROUPED BLIGHT CLASSES, AUGUST 9-22,1971



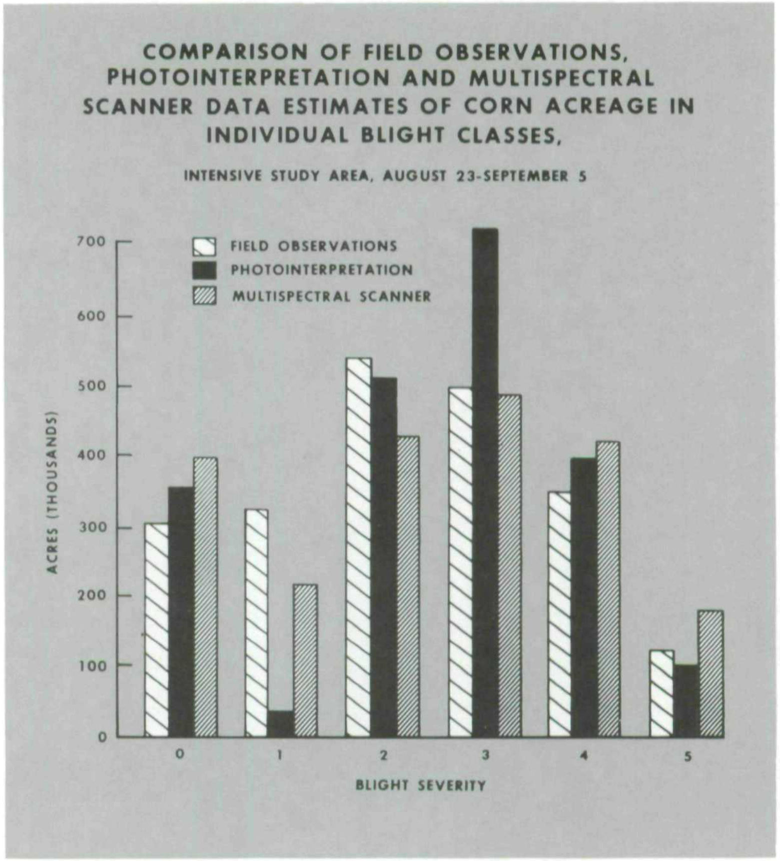
CORRELATION OF MSS AND FIELD ESTIMATES OF ACRES IN GROUPED BLIGHT CLASSES, AUGUST 9-22,1971



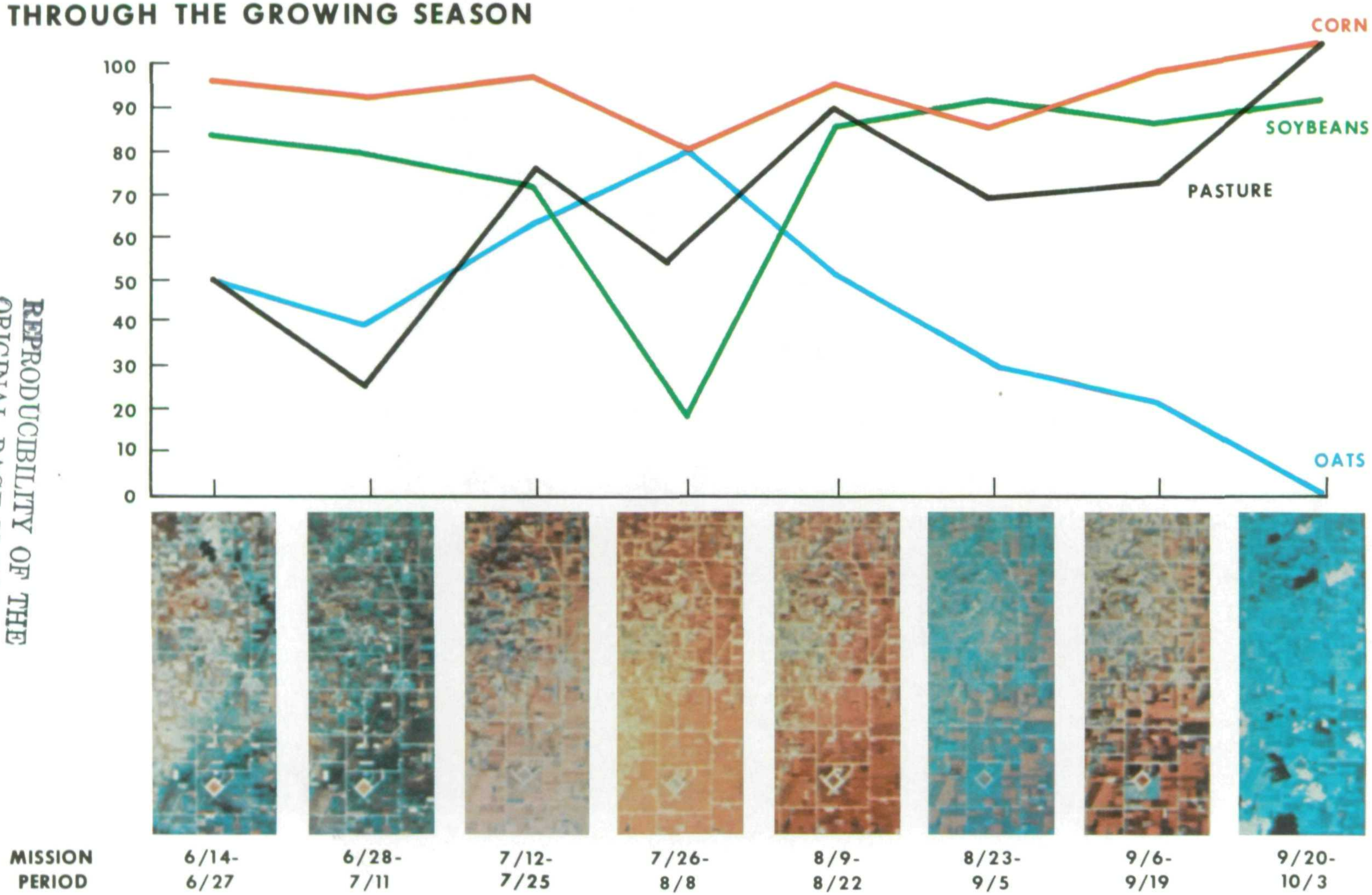
sensor data was quite good. Graphs showing these correlations illustrate the potential of remote sensing as a technique for monitoring crops for disease and other stresses.

From the standpoint of quantity and quality of data collected, the 1971 experiment was the largest and most successful remote-sensing project ever attempted in agriculture. The following statistics reflect the scale of the undertaking.

- 38 500 flight-line miles were flown by data-acquisition aircraft.
- 400 hours of RB-57F and C-47 aircraft flight time were expended.
- 18 000 frames of photographs were taken, processed, and reduced.
- 53 000 square miles of Corn Belt farmland were photographed biweekly (1800 square miles of which were evaluated biweekly).
- 800 people were involved in the experiment.
- 14 different state and federal organizations were involved in one aspect or another.
- 2500 man-hours were expended at LARS in photographic interpretation during the experiment.
- 1806 fields were visited biweekly by ground observation personnel.

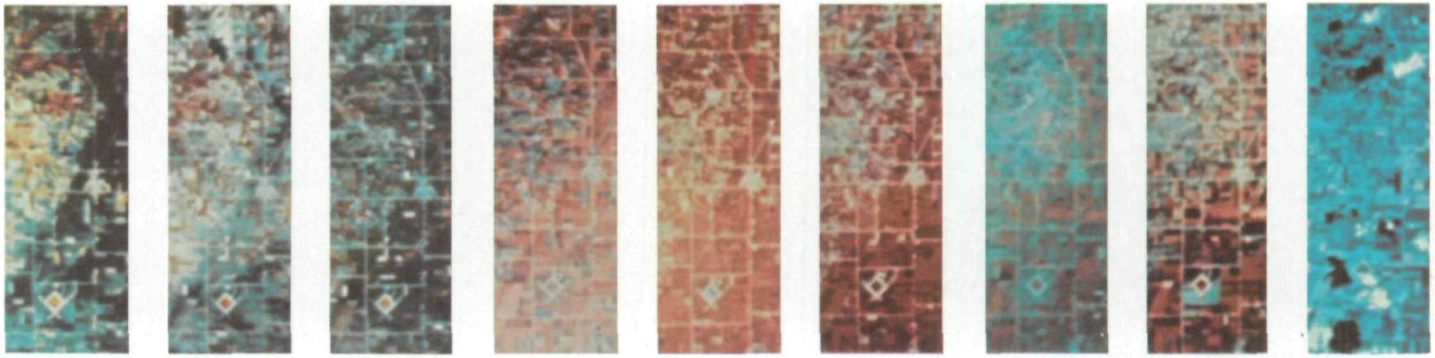


PHOTOINTERPRETATION OF MAJOR CROP SPECIES IN CENTRAL IOWA THROUGH THE GROWING SEASON

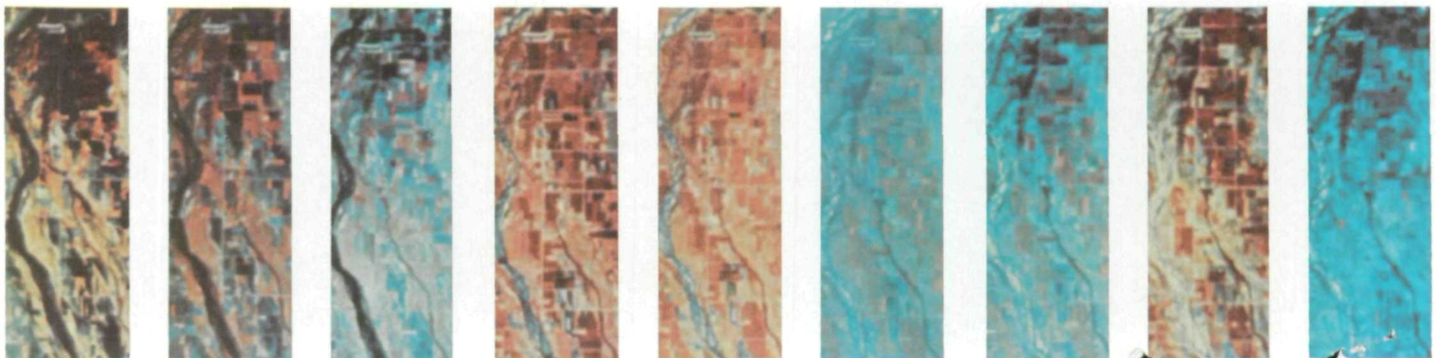


The graph above shows how well crops in a representative segment were identified using high-altitude, color infrared photographs similar to those below.

COLOR INFRARED PHOTOGRAPHS OF TWO SEGMENTS THROUGH THE 1971 GROWING SEASON



SEGMENT 116 - MAHASKA COUNTY, IOWA



MISSION PERIOD	5/10-6/1	6/14-6/27	6/28-7/11	7/12-7/25	7/26-8/8	8/9-8/22	8/23-9/5	9/6-9/19	9/20-10/3

SEGMENT 175 - BUTLER COUNTY, NEBRASKA

Series of high-altitude, color infrared photographs taken during the experiment is representative of photographs obtained for each sample segment in the experimental area.

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