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ANNUAL REPORT OF REMOTE SENSING OF CROP-HAIL DAMAGE

by

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TABLE OF CONTENTS

1. EXECUTIVE SUMMARY . . . 1

2. INTRODUCTION . . . 3

3. RESEARCH OBJECTIVES AND PLAN . . . 4

4. SUMMARY OF DATA COLLECTED . . . 8

   A. The Wheeler Storm . . . 8
   B. The Danvers Storm . . . 13
   C. The Galva Storm . . . 16
   D. The Sadorus Storm . . . 16
   E. The Charleston Storm . . . 19
   F. The Garrett Storm . . . 22

5. REMOTE SENSING AND COMPUTER MAPPING ANALYSIS . . . 26

   A. Background . . . 26
   B. Discriminant Analysis . . . 26
   C. Reasons for Failure of Predictive Models . . . 36
   D. Alternative Independent Computer Mapping Approach . . . 40

6. ADJUSTERS USE OF AERIAL PHOTOGRAPHY . . . 54

7. SUMMARY AND RECOMMENDATIONS . . . 57

REFERENCES . . . 59

APPENDIX A . . . 61

   Computer Mapping Instructions . . . 62
   Computer Mapping Program . . . 64

1. EXECUTIVE SUMMARY

The Illinois State Water Survey with funding from the Country Companies began in May 1974 a research and development project related to remote sensing of crop-hail damage. The two objectives of the project were: 1) to investigate the application and potential accuracy of using aerial photography to assess hail damage to Illinois' primary crops; and 2) to investigate the use of aerial photography as a means to delineate severe crop damage as an aid in directing and performing storm surveying. The Water Survey had done pioneering research along these lines in 1969-1970, and hoped to develop technologies transferable to the Country Companies as useful operational tools.

The first objective focused on developing an ability to better quantify losses within a particular field or area based on statistical analyses of the aerial photographs calibrated with selected field assessments. It was hoped that a more accurate, as well as an inexpensive, technique for assessing losses could be devised. The second objective dealt with developing methods by which crop-hail adjusters could use the aerial photographs for improving standard crop adjusting procedures. Comparable photographic data and field loss data were needed for the analyses to satisfy both objectives.

During the first year (May 1974-April 1975) of study, good field calibration data and natural color aerial photography data were collected on four Illinois storms. The analyses of these data sets suggested that a relationship between crop damage determined by standard adjusting techniques and that determined remotely by aerial photography could be established. The system designed to accomplish this primary objective of quantification of field losses contained only very basic analytic capabilities and was found to need further testing and refinement. The first year of study also revealed that aerial photographs could be used to delineate areas of severe storm damage in major storms. However, time did not permit refinement of these techniques. Therefore, a second year of study was proposed and funded by the Country Companies.

The objectives of the May 1975-April 1976 study remained unchanged from 1974-1975. The study was expanded to include more field loss assessments and to include the use of false color infrared film which was believed to offer the potential for better results than natural color film. Good field and aerial photography data were collected on six major storms in Illinois. Nearly 1,000 surface loss assessments were made by two adjusters provided to the project by the Country Companies, and over 800 aerial photographs were obtained for the study by employing a commercial photographic firm.

Extensive, sophisticated analyses were performed on all of the data. The final result is that accurate quantification of field losses using aerial photographs is not possible. The three basic reasons for this failure are: 1) errors associated with the measurements of film dye densities on the film; 2) the lack of a good relationship between the field calibration assessment (loss of yield measurements) and the measurement of recorded, reflected radiation on the film (in the film dyes); and 3) large variations in the reflected radiation measurements due to varying soil color, moisture differences, crop variety differences, and differing farm practices which confuse the discernment of the hail damage.

The second and third reasons are most critical. The crux of the second reason is the inability to discriminate between the two types of crop damage (direct and indirect) on the photographs and the fact that there is not necessarily a correspondence between the amount of physical damage (both direct and indirect) and estimates of losses to crop yields. Direct damage generally consists of destruction of plants (or yeild producing structure) and indirect damage is leaf area removal which ultimately reduces yield. There are an infinite number of combinations of direct and indirect damage which make up the total loss of crop yield. Furthermore, after a certain amount of physical damage has occurred, variations in soil moisture and color begin to show in the film (reason #3). These two reasons are somewhat related and when both are present the photographic prediction capability is at its worst.

Although objective number 1, quantification of field losses, could not be achieved, the research should not be considered a loss. A great deal has been learned about methods which are not successful, and quantification of the field losses might be achieved through different methods of photography and analyses. Some of the possibilities and recommendations are detailed in this report.

The results of the research pertaining to the second objective, use of aerial photographs to delineate severe hail damage for field operational applications, appear quite useful; as a consequence, the Country Companies formed an Aerial Survey Department which will be obtaining aerial photographs and supplying copies of them to the adjusters for use as a guide in their adjustments, particularly, in major large storms.

A pilot project was conducted during July-August 1975 to determine if the photographic approach would be an aid to the adjusters during their normal procedures. The overwhelming response from the adjusters who participated in the pilot project was positive. Therefore, a meeting was held with officials of Country Companies in November 1975 to outline the possible benefits of using the aerial photographs. It was concluded that use of the photographic approach would improve the efficiency and accuracy of the crop-hail adjusters and provide a better service to various Farm Bureau members and agencies. A second meeting was held to discuss implementation, including the possible costs and operational plans, of a potential aerial photography department within Country Companies. This was in-keeping with the goals of the Water Survey effort which was to develop useful technologies and to transfer these for cost-beneficial use of the Country Companies.

The decision to form the Aerial Survey Department was made by Country Companies in January 1976. The operational plan of the Department called for obtaining infrared aerial photographs on selected major storms during the summer of 1976. The aerial photographs (transparencies) would then be re-photographed and 5 x 5 prints supplied to selected adjusters for special training for use in adjusting.

The adoption of this approach meant that adjusters needed to be trained in the interpretation and use of the photographs. Thus, a 33-page handbook was prepared and a 2-day training session conducted for 25 adjusters. The preparation of the handbook and conduction of the training session were done by two Illinois State Water Survey staff members and two Country Companies crop-hail adjusters who had been assigned to work on the research project.

The Aerial Survey Department of the Country Companies is now in full operation. It has already obtained aerial photographs on one major June storm. The formation of this department was a direct result of techniques developed as part of this research project and the close cooperation between the Illinois State Water Survey staff and the Country Companies staff.

Another benefit from the project relates to a computer mapping program developed as part of the first objective. The ability to put the information for a particular field into map form was necessary so that areas of damage, the field average, and final adjustment figures could be determined. The inability to get desired results to satisfy the first objective was unfortunate; however, the quantified mapping program can be used to produce more accurate field maps based on loss assessments obtained by adjusters.

Some initial analyses have been performed using the program to study how different numbers of sample points (per field) and various sampling methods affect the accuracy of the average loss of yield for a field. More research is necessary before an optimum system combining knowledge about field sampling and the mapping program can be produced for use by the Country Companies. The production of a computer mapping system suitable for mapping crop-hail losses within a field, based on loss assessments by an adjuster, is the primary objective of the research project for 1976-1977. This research includes a) testing of a computer mapping program on many fields in areas where the Country Companies obtain aerial photographs in 1976, and b) investigating methods of improving the system to insure accuracy and compatibility with the Country Companies needs. Testing of the program will require that loss assessments be obtained by a crop adjuster (supplied by the Country Companies) from 75 to 100 insured fields. Maps and average field loss assessments (and payments) resulting from the computer mapping program will be compared with: 1) the final loss of yield in the field and payment as determined by Country Companies adjusters using standard techniques; 2) loss of yield (when available) as determined by an auditing adjuster; 3) final field yields from the farmer obtained by the Country Companies; and 4) general damage areas as shown on aerial photographs. The investigation into methods of improving the program include: 1) adapting the program to map fields without the aid of aerial photographs; and 2) performing various statistical analyses to determine if the adjuster sampling locations might be changed to obtain more accuracy.

2. INTRODUCTION

The rationale for use of aerial photography in the determination of crop damage is fairly simple in concept. The photographic image records differences in vegetation coloration. This coloration difference is a response of the plant's ability to reflect solar radiation and the ability of a photographic emulsion to record the reflected radiation (Towery et al., 1975). This basic technique has been used to detect crop diseases (Jackson, 1970; Philpott et al., 1969). Similar techniques have been used in other areas of remote sensing.

The first investigation into the use of this technique for crop hail damage was in 1969 (Barron et al., 1970; Changnon and Barron, 1971). Their results based on the study of one storm indicated that crop hail damage could be estimated with a reasonable degree of accuracy by visual inspection and various densitometer analyses. Further study was recommended but not performed because of lack of funding.

In the spring of 1974, the Water Survey initiated a multi-year photographic test and development project with funding from the Country Companies. The main objective was to investigate the application and potential accuracy of using aerial photography to assess hail damage to Illinois' primary crops. A secondary objective was to investigate aerial photography as a means to quickly delineate severe crop damage as an aid in directing and performing storm surveying.

The results of the 1974 study suggested that a relationship between crop damage determined by standard adjusting techniques and that determined remotely by aerial photography could be established. It also revealed that photographs from various altitudes could be used to delineate severe areas of damage (Towery et al., 1975). The system designed to accomplish the primary objective contained only very basic and preliminary capabilities and was found to need further testing and refinement. In particular, a more refined use of the photographs to delineate storms needed to be investigated. Therefore, a further 1-year study was proposed and funded by the Country Companies.

The purpose of this report is to discuss the results of the 1975-76 study. The objectives and data collection procedure appear in the first two sections, followed by a description of the storms and data collected. Then, the data analyses are described, followed by a discussion of the use of the photographs by the adjusters. The summary and recommendations are followed by Appendix A which contains a copy of the current mapping program and instructions for running the program.

3. RESEARCH OBJECTIVES AND PLAN

The objectives of 1975-1976 were unchanged from those of 1974. They were 1) to continue the investigation of aerial photography as a means to assess hail damage to Illinois' primary crops, and 2) to investigate use of aerial photography as a means to rapidly delineate areas of severe crop damage so as to direct surface storm surveying operations.

The data collection procedure developed in 1974 worked reasonably well (Towery et al., 1975) and was changed only slightly. The changes were:

1) that both color and infrared film were used;
2) photographic altitudes were established at 3,000, 5,000, and 12,000 feet above ground level (AGL) as opposed to variable altitudes in 1974;
3) more effort was made to perform data collection flights at various times after storms;
4) an additional adjuster was added to collect more crop loss information;
5) the adjuster's data collection procedure was made more systematic.

Initial information about the occurrence of crop damaging hailstorms was usually furnished by the Country Companies home office in Normal, Illinois. To be suitable for a photographic mission, a storm area had to cover three square miles in area and had to have a variety of damage ranging up to 60% or more. Consideration was given to the stages of crop growth in the area so that a wide variety of crop stages were photographed. If a storm was considered appropriate for photography after an inspection, a written copy of instructions containing the area to be photographed, flight altitudes, flight direction, film type and possible flight dates were delivered to the firm (Danner and Associates of Urbana, Illinois) contracted to perform the aerial photography.

Six hail storms occurred in 1975 which were considered to be suitable for photography. Figure 1 shows the location of these six storms and the name of a nearby town. All storms except one were photographed twice (two different dates), and usually from 3 altitudes with color reversal film and with false color infrared film. The time needed to take these photographs of a storm area was usually long (2 1/2 hours), and on four occasions clouds began to form and to shadow the ground before the mission was completed. In all cases, the first photographic mission occurred between 6 and 14 days after the storm occurred, and the second flight occurred between 14 and 21 days after the first flight.

After the storm was photographed, the film was processed by Precision Labs in Dayton, Ohio and returned as 9 inch by 9 inch transparencies within 3 days from the date of the photography. This 3-day turn around allowed inspection of the photographs and early detection of any complications which would make rephotographing of a damage area necessary.

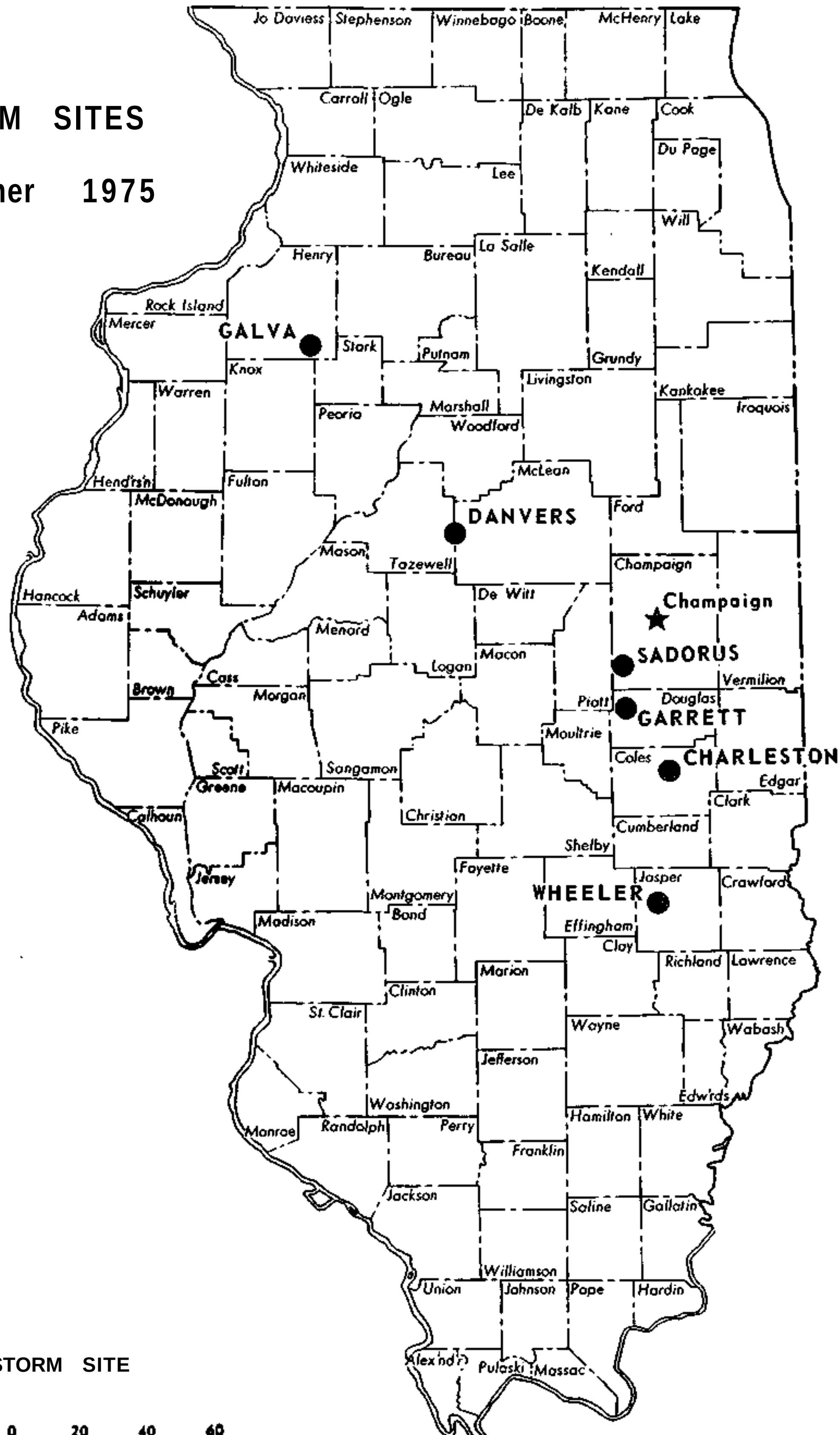
The transparencies were used in the analyses and to make selected color slides (2 x 2). Contact prints were obtained of all of the 5,000 ft photography to assist in the analyses. The project adjusters used slides made from the transparencies to determine fields from which ground truth measures could be gathered.

Some changes from 1974 were made in the 1975 field data collection method. A new adjuster's sheet was prepared (Figure 2). New data collection guidelines were also prepared. These guidelines were devised to obtain more complete coverage of the inspected field while considering constraints of photographic scale for taking density measurements. At least five measurement locales were established in each damaged field. The individual loss assessments, made along a line within a field, were usually between 100 and 300 feet apart. Separate, parallel, lines within a field were not more than 500 feet apart. The distance to each point along with the percentage loss measurement were recorded so that points could later be located on the aerial photograph.

The growing season in 1975 in Illinois began early and weather cooperated for one of the most productive crop yields ever recorded. Hailstorms were also plentiful. Six storms occurring between May 19 and August 18 were photographed and field adjustments taken. These storms were spaced from a week to a month apart and were each photographed because they covered large areas, had extensive damage, and damage occurred to a wide variety of crop stages. Each storm was unique and produced different information — therefore each storm is described separately.

STORM SITES

Summer 1975



● STORM SITE

20 0 20 40 60

miles

FIGURE 1

FIGURE 2. Adjuster's Data Sheet

Name		Address		County
Loss Date	Inspection Date		Stage/Loss	Stage/Inspection
Crop Type	Variety	# of Acres	Row Direction	Row Width
Section		Twp	Range	Population

Field Map (measure from corner of field)

Pt. No.	Direct Damage	Defoliation % dfl.	Defoliation % loss	Total loss
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
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19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				

Field Notes:
Include
1) other forms of damage,
2) date of planting.

4. SUMMARY OF DATA COLLECTED

Table 1 presents a brief summary of the storms studied and Table 2 reviews the photographic flights. In all flights, both color reversal aerial and infrared false color aerial films with a 9 inch by 9 inch (9 x 9) format were exposed. All first flight missions were planned to be flown at 3,000 ft, 5,000 ft, and 12,000 ft AGL. However, weather did not permit a complete 3-level mission to be flown on some days. The portion of the flight not completed would then be completed on the next day with suitable weather. Second flights were usually modified and only 3,000 ft and 5,000 ft AGL color and infrared color photography were taken.

A. The Wheeler Storm

1. General Description

The storm studied occurred on May 19, 1975 about 2 to 3 miles east of Wheeler, in south-central Illinois, and the first field inspection was on May 21. Information from local residents indicated there may have been two different hailstorm occurrences.

Inspection was conducted mainly on wheat fields with some observation of oats and clover. Corn and beans were just barely out of the ground so the hail had very little effect on them; however, cut off bean plants were found in one field. It would be impossible to detect the beans on aerial photographs at this early stage.

Crop damage (loss of yield) was 100% for some wheat fields. The decision to photograph the storm was made because of the presence of small grain fields. No data had been gathered on these crops in the 1974 study. An acceptable number of small grain fields made it feasible to photograph the area.

2. Photography

Only one photographic flight mission occurred because most of the small grain fields were harvested by the time the second flight would have taken place. Sections 1, 12 and 18 in Crooked Creek Township (Figure 3) were photographed on May 23 and 24. The flight path direction was from north to south. Twenty infrared color exposures were taken on May 23 at approximately 10:40 AM CDT from 3,000 ft and 5,000 ft AGL. Clouds developed and caused the rest of the flight to be cancelled until the following day. On May 24 from 9:30 AM to 10:15 AM CDT a total of 29 color transparencies were taken at 3,000 ft, 5,000 ft, and 12,000 ft AGL.

3. Field Study

Point assessments of hail damage were taken from May 26 through May 28 by the two adjusters assigned to this project for the summer 1975. Forty-eight points were taken in seven wheat fields (Table 3). Some oats and alfalfa fields were inspected but no point loss measurements were taken.

Table 1. 1975 Storms Studied.

Storm Date	Storm Identification	Loss Adjustment Period	Number of Fields Studied				Number of Points			Number of Crop Stages		
			Corn	Bean	Other*	Total	Corn	Beans	Other	Corn	Beans	Other
May 19	Wheeler	May 26—May 28	0	0	9	9	0	0	49	0	0	2
May 30	Danvers	Jun 30—Jul 10	10	6	2	18	85	56	16	4	1	2
June 14	Galva	Jul 21—Jul 30	14	7	1	22	119	66	4	5	2	1
July 12	Sadorus	Aug 06—Aug 28	8	9	(1)	17(1)	84	160	(4)	3	2	1
July 17	Charleston	Aug 03—Oct 03	15	15	0	30	114	153	0	7	5	0
August 18	Garrett	Sep 08—Sep 17	5	1	0	6	55	4	0	2	1	0
Totals			52	38	12	102	457	439	70	21**	11**	6**

* Includes wheat, oats, alfalfa, and Foundation corn

** Some crop stages were duplicated from one storm to the next. The corn stages include: 6-, 7-, 8-, 9-, 10-, 11-, 13-, 16-, 17-, and 18-leaf, tassle, silked, brown silked, blister, soft dough, dented, and near mature; those in soybeans were V-1, V-2, R-5, R-6, R-6.5, R-7, R-8, R-9; and boot and jointed in oats and wheat.

Table 2. Summary for 1975 Aerial Photography.

Flight No.	Name	Storm Date	Photography Date	No. of Transparencies	Exposure Cost	Contact No.	Prints Cost	Flight Cost	Total Cost
1	Wheeler	May 19	May 23	55	605.00	11	105.85	140.00	986.05
2	Danvers	May 30	Jun 06	87	957.00	33	238.85	60.00	1255.85
3	Danvers	May 30	Jun 27	26	286.00	9	56.25	60.00	402.25
4	Galva	Jun 14	Jul 08	97	1067.00	40	282.35	120.00	1469.35
5	Galva	Jun 14	Jul 16	101	1111.00	22	179.00	120.00	1410.00
6	Sadorus	Jul 12	Jul 21	91	1001.00	90	614.85	12.00	1627.85
7	Charleston	Jul 17	Jul 26	37	407.00	8	85.90	42.00	534.90
8	Sadorus	Jul 12	Aug 07	111	1221.00	0	0	12.00	1233.00
9	Danvers	May 30	Aug 11	75	825.00	12	79.80	60.00	964.80
10	Charleston	Jul 17	Aug 20	102	1122.00	26	172.90	42.00	1336.90
11	Garrett	Aug 18	Aug 23	74	814.00	20	133.00	25.00	972.00
12	Garrett	Aug 18	Sep 09	20	220.00	-	-	25.00	245.00
Sub-Totals				876	9636.00	271	1948.75	718.00	12303.75

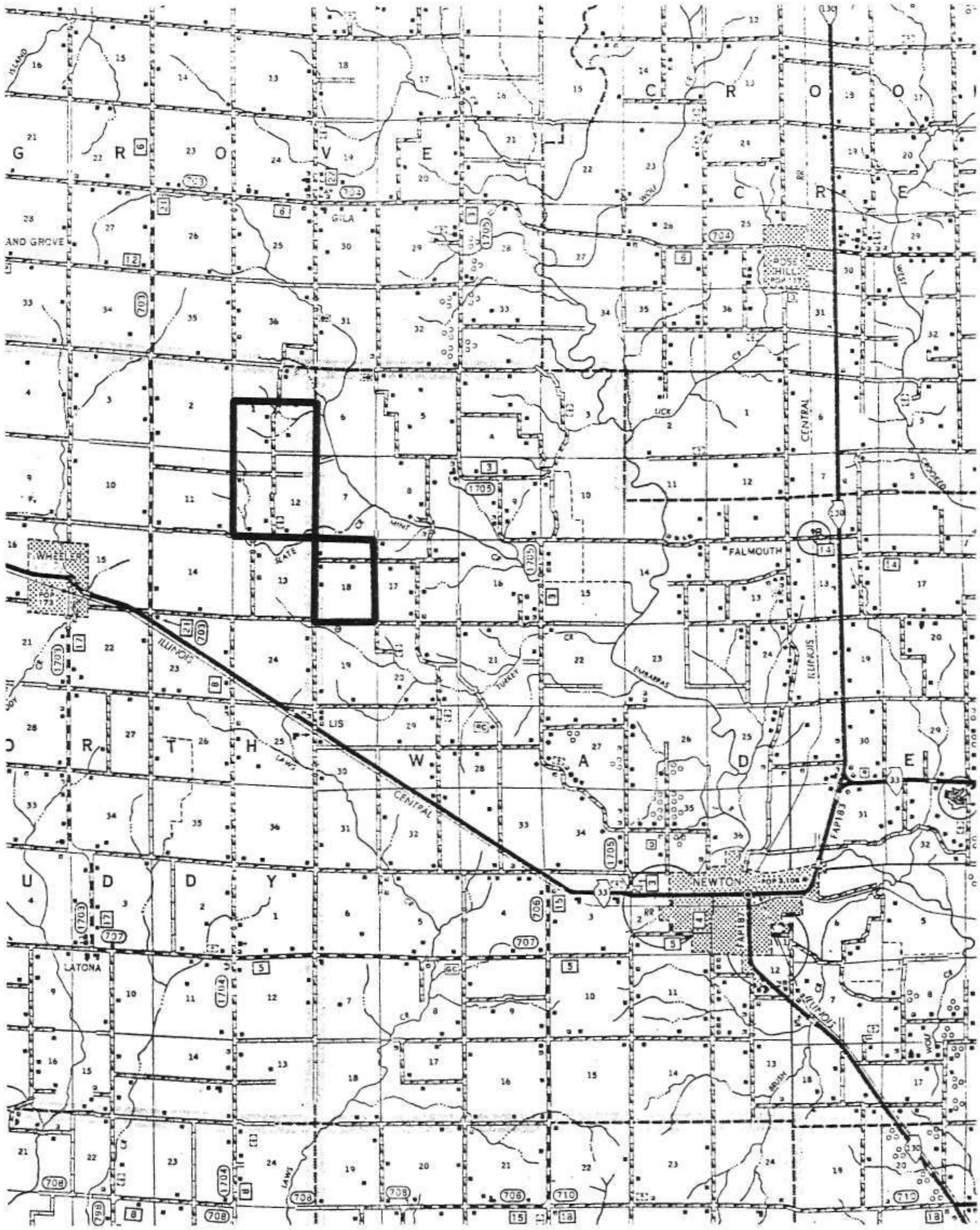


FIGURE 3. Area Photographed of the Wheeler storm

Table 3. Damage Assessments for the May 19 Storm at Wheeler.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	1	Wheat	Jointed	1	May 28
2	6	Oats	Jointed	No measurement	May 28
3	40	Oats	Jointed	No measurement	May 28
4	7	Wheat	Bloom	1	May 27
5	40	Wheat	Bloom	3	May 27
6	37	Wheat	Bloom	2	May 27
7	12	Wheat	Bloom	5	May 26
8	9	Wheat	Bloom	4	May 26
9	66	Wheat	Bloom	32	May 26

B. The Danvers Storm

1. General Description

This large storm occurred on May 30 between 1:30 PM and 4:30 PM. It reportedly covered an area from south of Minier to north of Carlock — approximately 20 miles in length. Field observations on June 2 revealed that damage in some areas was as wide as 5 miles. The storm covered several townships along the NE-SW line from Carlock to Minier and affected at least two counties: Tazewell and McLean.

Crops in the area consisted mainly of corn and beans with scattered small grain fields. The corn stages were between 4 to 10 leaf and the beans were in the V-1 stage when the hail occurred. Maximum damage was 100% for beans and 80% in corn. Severe damage covered a wide area and dropped to no damage over short distances. Gradual changes in damage were difficult to locate in this particular storm.

2. Photography

The area photographed was just north and east of Minier (Figure 4). The sections included were 13 and 14 in Little Mackinaw Township, and 17 and 18 in Allen Township. Photographs were taken at 3,000 ft, and 5,000 ft altitudes and two 12,000 ft spot photographs were obtained. This storm covered an extensive area; therefore a flight line from Minier to Danvers was photographed to determine the feasibility of using 12,000 ft altitude photography to detect overall damage patterns in early storms. There was some doubt as to whether this storm would be detectable because of the early stages of the crops. The storm area was photographed from 3 altitudes in both infrared and natural color films and healthy crops could be detected by visual inspection of the photographs. Damaged crops were virtually destroyed and usually only bare ground was seen in the photography. This first flight took place June 6. A total of 87 exposures were taken.

A second flight of this area was taken three weeks later on June 27. The two types of film were used at 3,000 ft and 5,000 ft AGL, but cloud shadows obscured most of the information on the infrared color photography at 3,000 ft AGL. Only 31 useable exposures were obtained.

A third flight of this area was taken on August 11. The purpose of this flight was to determine if crop damage could be detected 2 1/2 months after the storm occurrence. Therefore, the photographic mission plan was the same as the first flight and 75 exposures were taken. Comparison of this photography with early flights indicated hail damage was relatively obscured after the 2 1/2 month recovery period.

3. Field Study

Crop loss adjusting in the Danvers area began June 30 and was completed on July 10. During that time, a total of 18 fields were investigated and 157 loss of yield assessment points were obtained (Table 4). The majority of the fields adjusted were corn fields because this storm was early and many beans were replanted. Also two oats fields were included in the assessments.

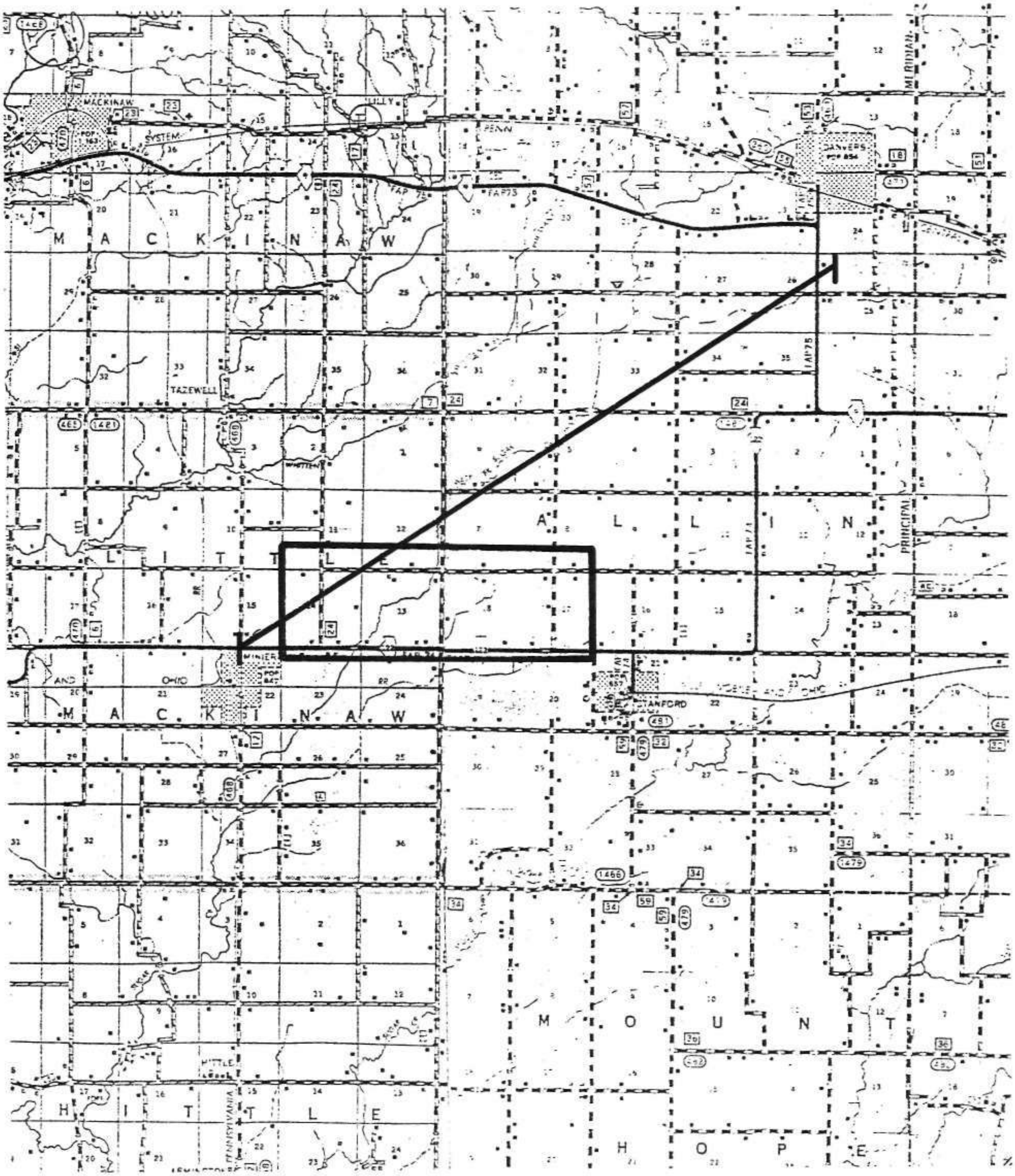


FIGURE 4. Area photographed of the Danvers storm and flight line of 12,000 ft AGL photography

Table 4. Damage Assessments for the May 30 Storm at Danvers.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	30	Oats	Jointed	7	June 30
2	10	Corn	6-leaf	2	June 30
3	50	Soybean	V-1	14	July 08
4	35	Corn	9-1eaf	15	July 08
5	15	Soybean	V-l	5	June 30
6	77	Corn	8-leaf	17	July 01
7	40	Soybean	V-l	7	July 01
8	76	Corn	8-leaf	14(4)	July 02
9	40	Corn	8-leaf	7	July 02
10	40	Corn	8-leaf	8	July 02
11	10	Soybean	V-l	4	July 07
12	20	Oats	Boot	9	July 07
13	37	Corn	7-leaf	6	June 30
14	90	Soybean	V-l	14	June 30
15	55	Corn	8-leaf	2	June 30
16	80	Soybean	V-l	11	July 10
17	75	Corn	8-leaf	10	July 10
18	10	Corn	7-leaf	3	June 30

C. The Galva Storm

1. General Description

The storm in the Galva area occurred on June 14 in the afternoon between 1:00 and 5:00 PM. The storm was about 7 miles wide and over 20 miles long. The storm moved from the west-northwest. Hail was said to have piled up as high as 16 inches on level ground and washed into four foot drifts in the gulleys and ditches. The area is quite rolling compared to areas of the previous storms. One adjuster surveyed the area on June 17. This was followed by another inspection on June 19 by the Water Survey staff to determine the area to be photographed.

The inspections showed that crops were slightly more advanced than those near Minier. The corn ranged from 7 leaf to 13 leaf and the beans were between V-1 and V-2. At times it was difficult to determine the stage of crops because they had been so badly damaged. Quite a few oat fields were found in the area and all of them appeared to have headed and some were even turning yellow. Damage ranged from total loss to nil along a five mile north-south line east of Galva. This was the area chosen for photographic survey (Figure 5).

2. Photography

The flight began in an area of no damage in Section 2 of Lynn Township and extended north through sections 35, 26, 23, and 14 of Galva Township. The five sections were flown at 3,000 ft, 5,000 ft, and 12,000 ft AGL and photographed in both the color and infrared color aerial films. A 12,000 ft AGL flight line was made perpendicular to the storm path to determine the width of the storm. This flight line extended from south of Galva to east of Kewanee. The flight took place on June 27. Cloud shadows rendered the 3,000 ft and the 12,000 ft AGL infrared color film and the 12,000 ft AGL natural color film useless for purposes of analysis leaving 56 exposures available for study. Poor weather conditions delayed a second flight until July 8 to rephotograph the altitudes and film types that were lost during the first flight because of cloud cover. Forty-one transparencies came from this reflight. On July 16 a third photographic mission of the area was accomplished yielding 50 color exposures and 51 infrared color exposures.

3. Field Survey

The damage assessments for the Galva area were obtained between July 21 and July 30. Twenty-two fields were inspected and 189 point assessments were made (Table 5).

D. The Sadorus Storm

1. General Description

On July 12 at approximately 5:00 PM a hailstorm occurred just south of Sadorus and extended to south of Ivesdale. The storm moved from northwest to southeast and affected Sections 3, 4, 5, 8, 9, 10, 11, 12,

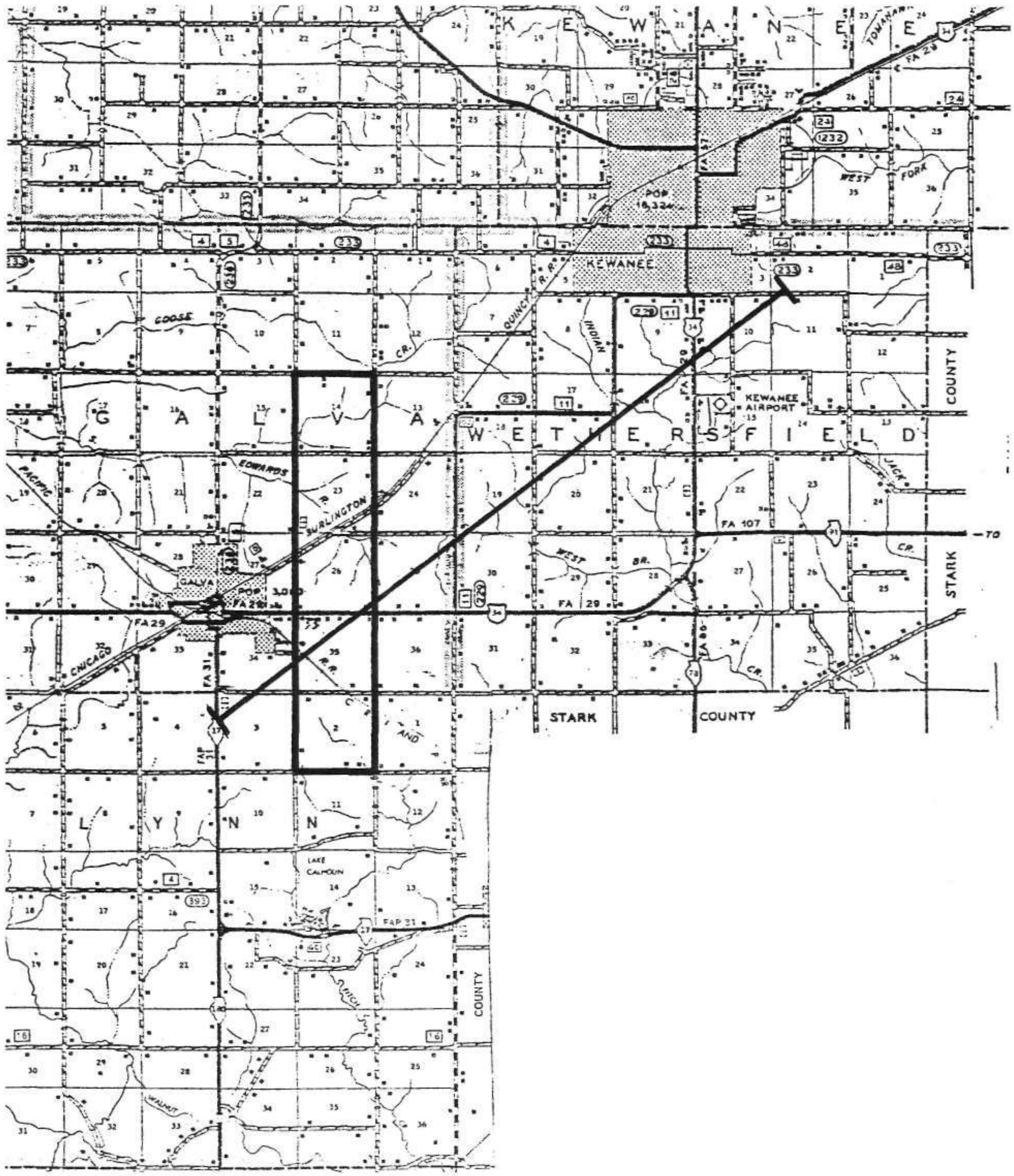


FIGURE 5. Area photographed of the Galva storm and flight line of 12,000 ft AGL photography

Table 5. Damage Assessments for the June 14 Storm at Galva.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	*	Corn	9-leaf	11	July 22
2	*	Corn	8-leaf	8	July 22
3	*	Corn	9-leaf	12	July 22
4	*	Corn	13-leaf	9	July 30
5	30	Corn	13-leaf	11	July 29
6	*	Corn	10-leaf	3	July 25
7	*	Corn	9-leaf	28	July 28
8	50	Soybean	V-1	9	July 25
9	130	Corn	10-leaf	7	July 30
10	*	Corn	9-leaf	6	July 30
11	*	Corn	11-leaf	8	July 22
12	*	Soybean	V-2	8	July 25
13	*	Soybean	V-2	14	July 29
14	20	Soybean	V-2	12	July 21
15	34	Corn	8-leaf	8	July 21
16	6	Oats		4	July 21
17	30	Corn	11-leaf	8	July 28
18	*	Soybean	V-2	9	July 25
19	*	Soybean	V-2	14	July 29
20	*	Corn		0, control field	
21	*	Soybeans		0, control field	
22	*	Corn		0, control field	

* Acreage was not recorded on data sheets

13, 14, 15, 16, and 17 of Sadorus township. Residents indicated the numerous hailstones were usually 1/4 to 1/2 inch in diameter and some were 3/4 inch in diameter. Hail collected in the fields and ditches and was visible the next day. One adjuster and Survey personnel inspected the area Tuesday, July 15 and did an inspection and mapping of the area the following day.

The crops were staged at R-6 and R-7 for beans and silked, brown silked, and blistered stages for corn. Wheat fields in the area had been harvested before the storm occurred.

The width of the severely damaged area was small (less than 1/2 mile). Loss of yield ranged from nil to 95%. Defoliation of corn and plant damage to beans was significant especially at the center of the storm area. Some stalk bruise damage was evident and beans were often topped.

2. Photography

The storm south of Sadorus consisting of 14 sections was photographed from 5,000 ft and 12,000 ft AGL on July 21. At 3,000 ft AGL only six sections covering the central storm area were photographed (Figure 6). The photography at each altitude was done with both color and infrared color film and all 90 transparencies were made into prints. The prints were utilized in an experiment to see if the adjustor's felt the photographs could be a useful adjusting aid. This experiment and its results are described later in the report.

A second flight on August 7 yielded color and infrared color transparencies at 3,000 ft and 5,000 ft AGL. The roll of infrared color film was not properly color balanced and the infrared photography was then retaken on August 22. A total of 199 useable photographs were taken of the storm.

3. Field Survey

Adjusting of this storm began August 6 and ended August 28. Seventeen fields were chosen from the six section area photographed at 3,000 ft. Over 200 surface points were assessed for damage (Table 6). Percentages of loss of yield ranged up to 95%.

E. The Charleston Storm

1. General Description

On July 17 in the early evening a hailstorm occurred 2-3 miles north of Charleston. The worst damaged area was 1 1/2 miles west of Fairgrange. Water Survey personnel examined the area on July 21, and a follow-up trip with an adjuster was taken on July 23. The portion of the storm inspected was contained in Seven Hickory Township although the storm encompassed a much larger area (about 10,000 acres).

The hailstorm reportedly was followed by heavy rains. Large ponds of water were evident in fields. The hail caused considerable damage in many areas. Loss of yield ranged up to 100% in the inspected area. A

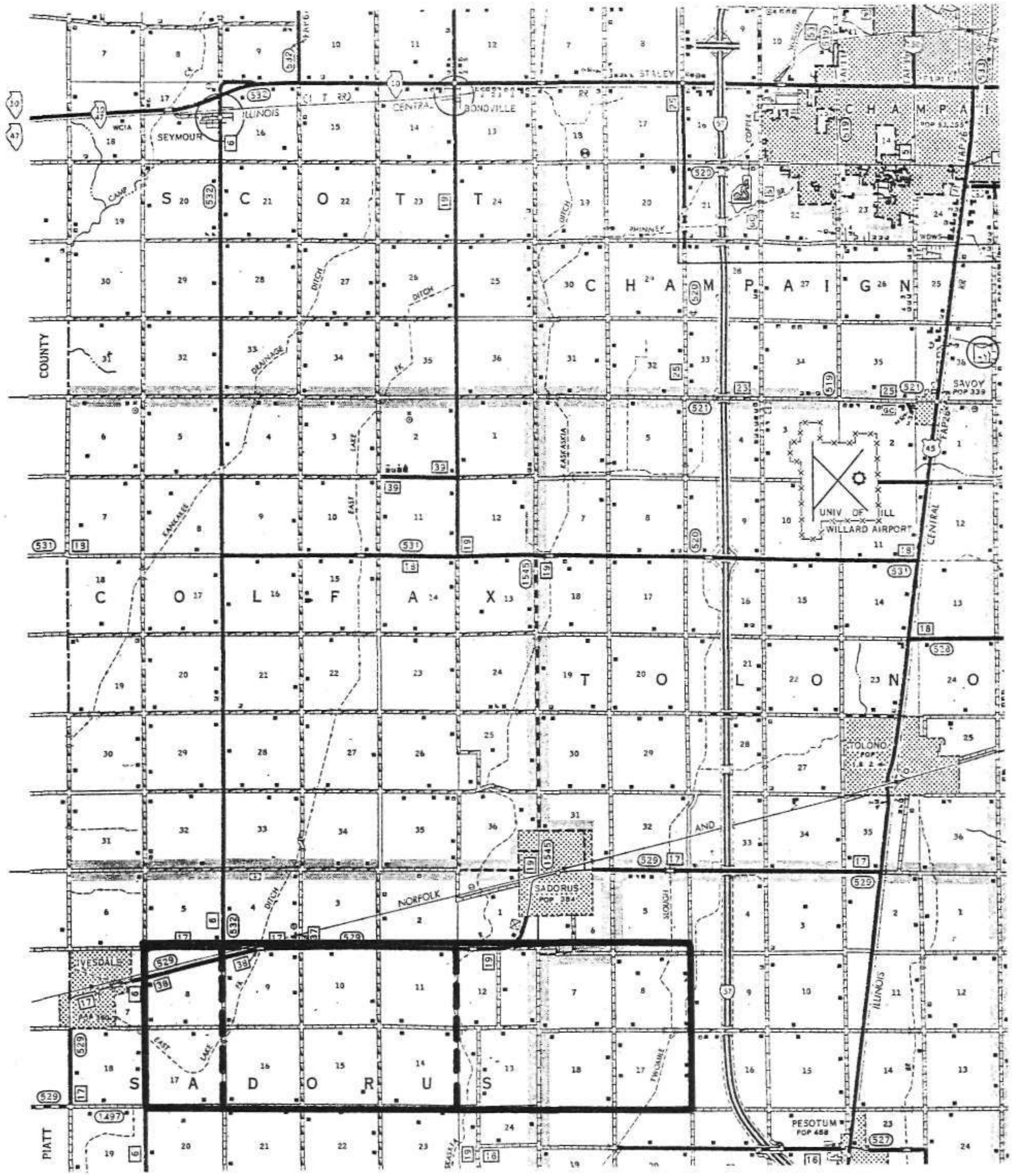


FIGURE 6. Area photographed of the Sadorus storm. Dashed lines indicate area of 3,000 ft AGL photography.

Table 6. Damage Assessments for the July 12 Storm at Sadorus.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	25	Corn	Silk	8	August 13
2	80	Corn	Brown silk	21	August 13
3	80	Soybean	R-6	16	August 21
4	80	Corn	Blister	17	August 21
5	120	Soybean	R-7	32	August 18
6	80	Corn	Brown silk	10	August 21
7	80	Soybean	R-7	17	August 18
8	30	Corn		8	August 21
9	20	Soybean	R-7	8	August 07
10	30	Corn	Silk	8	August 07
11	70	Soybean	R-6	8	August 06
12	10	Corn	Silk	6	August 08
13	40	Soybean	R-7	8	August 06
14	40	Corn		24	August 28
15	40	Soybean	R-7	13	August 12
16	20	Corn	Silk	6	August 12
17A	40	Soybean	R-6	17	August 28
17B	40	Soybean	R-6	17	August 12

variety of crop stages was present in the area. Some of the crop stages had not been available in previous storm areas in 1975. Corn stages ranged from 16 leaf to early milk and bean stages were from V-2 to R-8.

2. Photography

The first aerial photography mission on July 26 was taken of sections 27, 28, 21, 22, 15, and 16 of Seven Hickory Township at 3,000 ft, 5,000 ft, and 12,000 ft AGL in both infrared color and natural color films (Figure 7). The infrared film came from a roll of film which was not properly color balanced and the data could not be used in analysis.

The second flight in the Charleston area was conducted on August 20. All specified photography for the first flight was taken resulting in a total of 139 usable photographs from the Charleston area.

3. Field Survey

Field loss assessments were done intermittenly from August 3 through October 3. Thirty fields were inspected and over 250 field measurements were taken (Table 7).

F. The Garrett Storm

1. General Description

On August 18 at approximately 9:00 PM hail fell between the towns of Garrett and Ficklin. The storm was relatively small, covering only 4 sections of land. The hailstones were reported to be of moderate size, but usually less than one-inch in diameter. The storm duration was about five minutes.

The storm area was first visited on August 25. Stages of crops ranged from soft dough to nearly mature for corn and R-9 to R-11 in the beans. No 100% damage areas were detected. Most of the damage consisted of direct plant damage and shatter loss to the beans and leaf and ear damage to the corn. Most of the stages of crops had not been previously investigated; therefore, the area was photographed.

2. Photography

Sections 27 and 34 and half of sections 26 and 35 of Garrett Township (Figure 8) were photographed from 3,000 ft, 5,000 ft, and 12,000 ft AGL in both color and infrared color films on August 23.

The second flight in this area was made at 5,000 ft AGL only because it was thought that the stage of maturity of the crops might obscure the effects of the hail damage. Also harvesting of beans had already begun by September 9, the day the photography was taken. Both sets of photography were satisfactory for analysis purposes.

3. Field Survey

The storm occurred when crops were near maturity, and by the time adjusting began many of the bean fields were already being harvested.

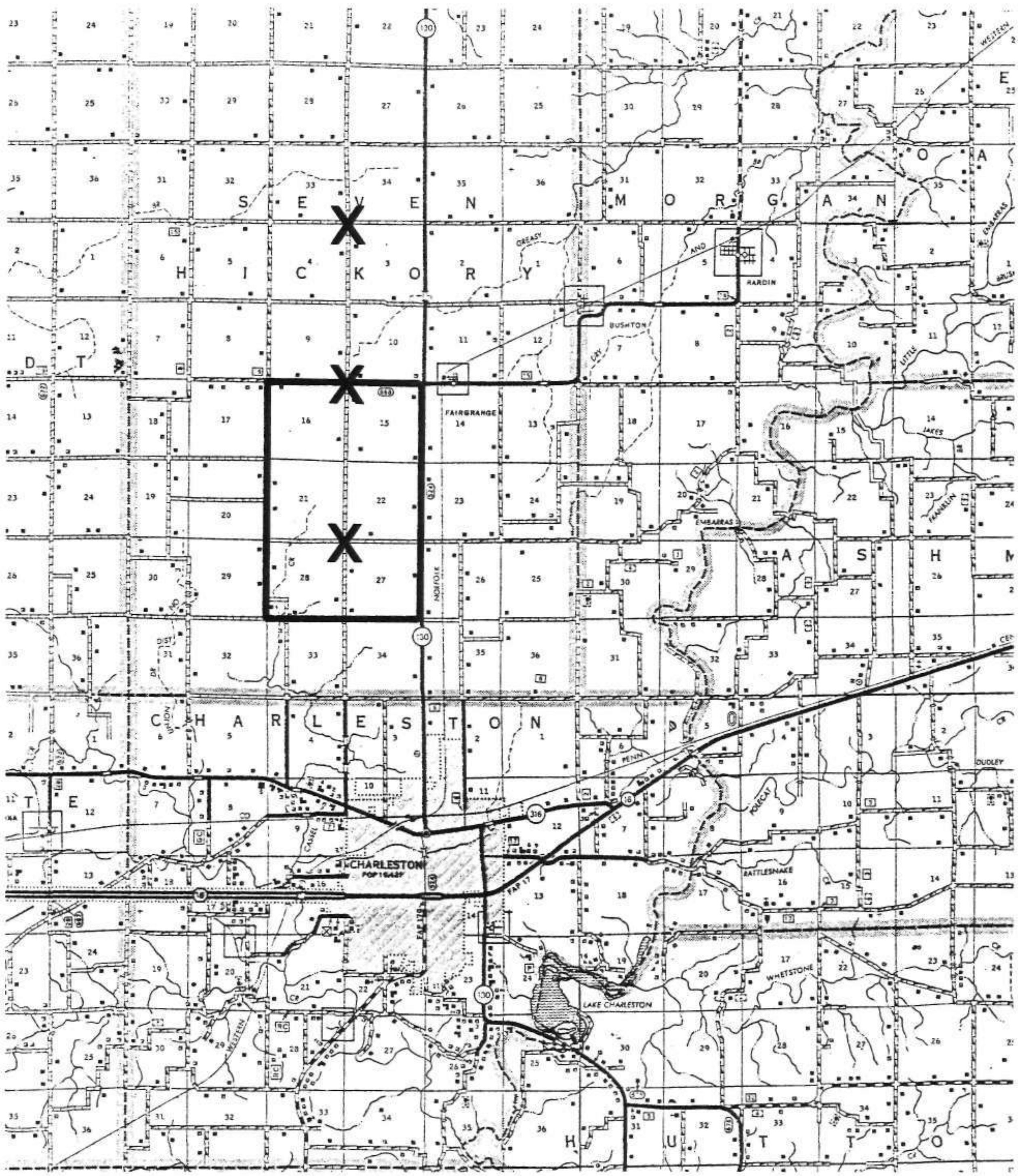


FIGURE 7. Area photographed of the Charleston storm.
X indicates locations of 12,000 ft AGL
photography.

Table 7. Damage Assessments for the July 17 Storm at Charleston.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	40	Corn	Tassle	15	September 10
2	40	Corn	Silk	8	September 08
3	20	Corn	Tassle	6	September 04
4	20	Corn	17-leaf	14	August 04
5	40	Corn	Tassle	12	August 25
6	20	Corn	16-leaf	6	September 24
7	40	Corn	16-leaf—tassle	19	October 02
8	30	Corn	Soft dough	14	September 18
9	80	Corn	Tassle—silk	15	September 22
10	15	Corn	Tassle	4	September 22
11	40	Soybean	R-6	8	September 23
12	40	Soybean	R-6	8	September 23
13	100	Soybean	R-6	14	September 30
14	20	Soybean	R-6	8	September 24
15	40	Soybean	V-2	7	September 23
16	60	Soybean	R-5--R-6	16	September 22
17	220	Soybean	V-2	11	October 03
18	40	Soybean	R-6	13	August 25
19	40	Soybean	R-8	5	September 02
20	30	Soybean	R-5	12	September 02
21	40	Soybean	R-6.5	4	August 29
22	75	Soybean	R-6	10	August 03
23	60	Soybean	R-6.5	8	August 28
24*	60	Soybean	R-6	29	August 04

* Nil fields used as controls make up the discrepancy of number of fields.

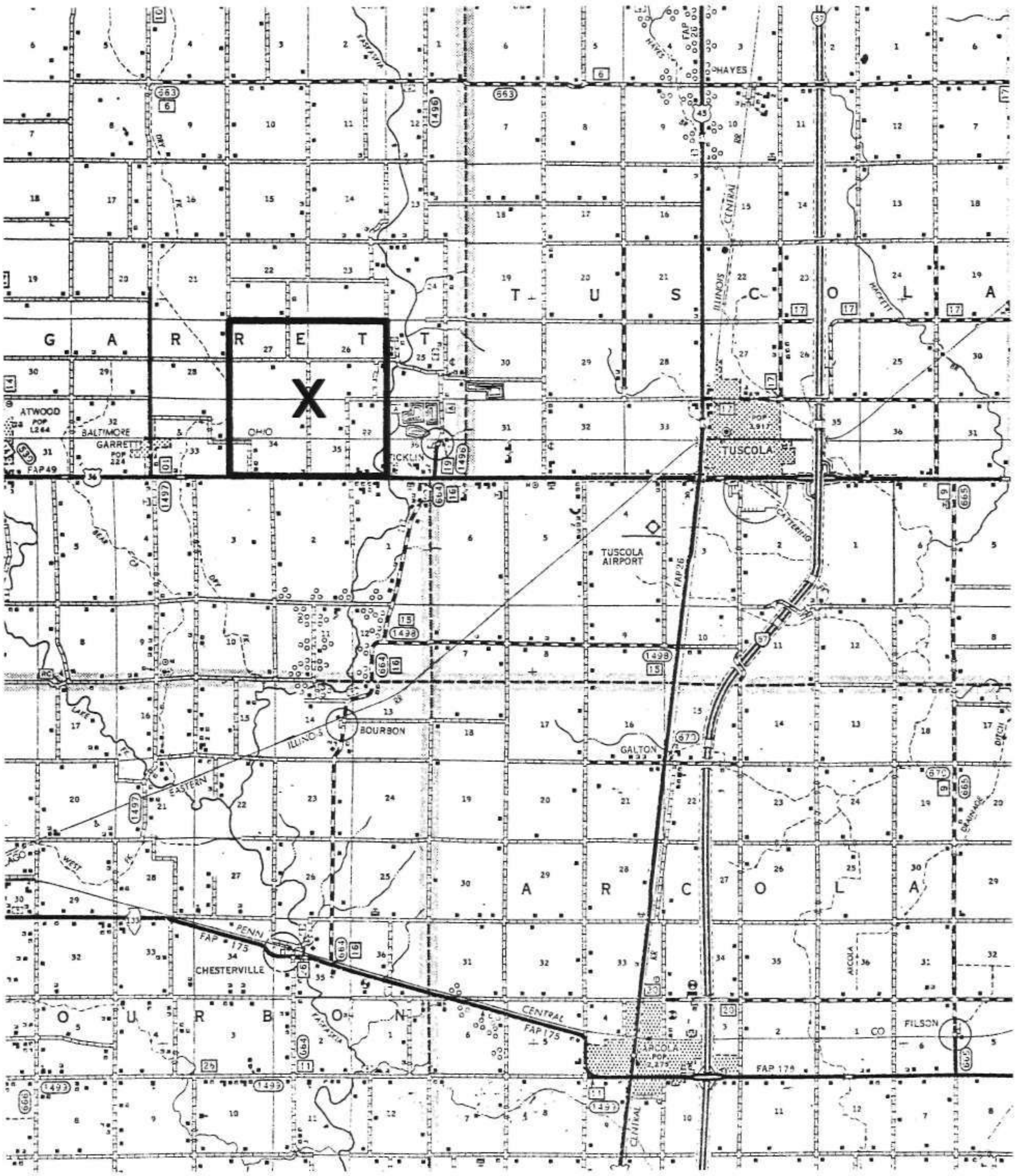


FIGURE 8. Area photographed of the Garrett storm. X indicates location of 12,000 ft AGL photography.

Only six fields (Table 8) were actually inspected for a total of 59 surface measurements.

5. REMOTE SENSING AND COMPUTER MAPPING ANALYSES

A. Background

The report of research (Towery *et al*., 1975) conducted from May 15, 1974 through May 14, 1975 included discussion of the following items concerning the remote sensing analysis:

1. Development of a screening program for the densitometric measurements. The program has the capabilities of determining the simple linear correlation coefficient between any of the damage estimates and the raw or ratioed density values. Scattergram plotting was included as well.

2. Development of a regression model to analyze the raw or ratioed density values. The regression model used was a multiple-curvilinear one dependent (percent total loss of yield) and three independent (density measurements) variable equation.

3. Development of a computer mapping program to display the percent total loss of yield in the field based on predicted values from the regression model. The mapping program included the capability of area measurement and determining an average of the percent loss of yield to the crop over the entire field.

Although the early results of the regression model and the mapping program looked promising, the predictive capability of the regression model was found to be ineffective. (Further discussion of some of the reasons for this result is set forth in Part C of this section.) It was then decided to abandon the regression approach and work with a model in which the information content of the dependent variable (percent crop loss of yield) was reduced by assigning the damage values to 5 or 6 damage groups, and then use a discriminant analysis to develop functions for separating the groups. This approach is fairly similar to methods of statistical pattern recognition modeling used in satellite image analysis. The principal reason for undertaking a fairly exhaustive discriminant function analysis of the data is that if the data cannot be effectively identified as distinct groups by the discriminant functions, then it is extremely unlikely (if not impossible) that a regression model could successfully be used for prediction of crop loss.

B. Discriminant Analysis

Following the assumption that there is a direct relationship between the transmission densities obtained in the laboratory from the aerial photography and the field damage estimates furnished by the crop adjustors, a multivariate discriminant analysis was applied to the

Table 8. Damage Assessments for the August18 Storm at Garrett.

Field Number	Acreage	Type of Crop	Stage	Number of Measurements	Date Adjusted
1	20	Corn	Dented	11	September 10
2	80	Corn	Near mature	7	September 10
3	20	Corn	Dented-near mature	16	September 08
4	7	Corn	Dented	6	September 09
5	80	Corn	Near mature	15	September 09
6	40	Soybean	R-9	4	September 17

existing data. In simplest terms, the purpose of discriminant analysis is twofold: first, as an inferential tool, it is used to differentiate between two (or more) groups or classifications as defined by the researcher. Secondly, as a predictive tool, discriminant analysis is utilized to assign new observations to a particular group or classification with a minimum probability of error. The best use of discriminant analysis is in its multivariate form, where two or more continuous variables are utilized to differentiate among the various groups. The importance of the resulting discriminant model is that it can then be employed to assign new observations to a particular group. If the discriminant model performs well, a plot of the observations for the various groups should reveal distinct clusters illustrated in Figure 9. This is indicative that discrimination power of the model is high and prediction will be good.

The data set chosen for the quantitative multivariate analysis was from the Sadorus hailstorm. The data set consisted of 10 bean fields and 8 corn fields. Data for one of the bean fields (S05) and the one corn field (S02) were not analyzed. The data were used as a test of the prediction capability of the model. The Sadorus storm (July 12. 1975) occurred at crop stages which were sensitive to severe damage. The crops were at optimum growth for photography. The data set was of sufficient size and variability for multivariate discriminante analysis.

Since the photographic mission of the Sadorus storm site was flown at 3,000 and 5,000 ft altitudes using both color and infrared film types, 4 (2 films x 2 altitudes) master data sets were available. In addition, the adjusters' field data included 4 types of damage estimates (in percentages) for each field data point. For bean fields these include the following: 1) direct damage, 2) plant damage, 3) loss of yield due to plant damage, and 4) total loss of yield. With regard to corn fields, the following were available: 1) direct damage, 2) defoliation damage, 3) loss of yield due to defoliation, and 4) total loss of yield. Each of these 4 major damage estimates were used as a dependent variable in a discriminant analysis. Using frequency histograms, all the observations were plotted for each type of damage, and using "natural" breaks in the data groups, classifications of damage for corn and beans were created. The independent variables consisted of 2 slightly different data sets, one based on the color imagery and one on the infrared imagery. These included 8 separate measurements from the color imagery [red, green, blue, and visual raw transmission densities (anti-logarithms) as well as red/green, green/blue, red/blue, and red/visual ratioed transmission densities (anti-logarithms)] and 8 for the infrared imagery [infrared, red, green, and visual raw transmission densities (anti-logarithms) as well as infrared/red, red/green, infrared/green, and infrared/visual ratioed transmission densities (anti-logarithms)].

Since the adjustment procedures used for evaluating crop damage differed for corn and beans the data were separated on this basis for the quantitative analysis. For a particular type of damage (i.e., total loss of yield), a discriminant analysis model was constructed for the data set. Therefore, 8 different analyses were performed and included the following for total damage:

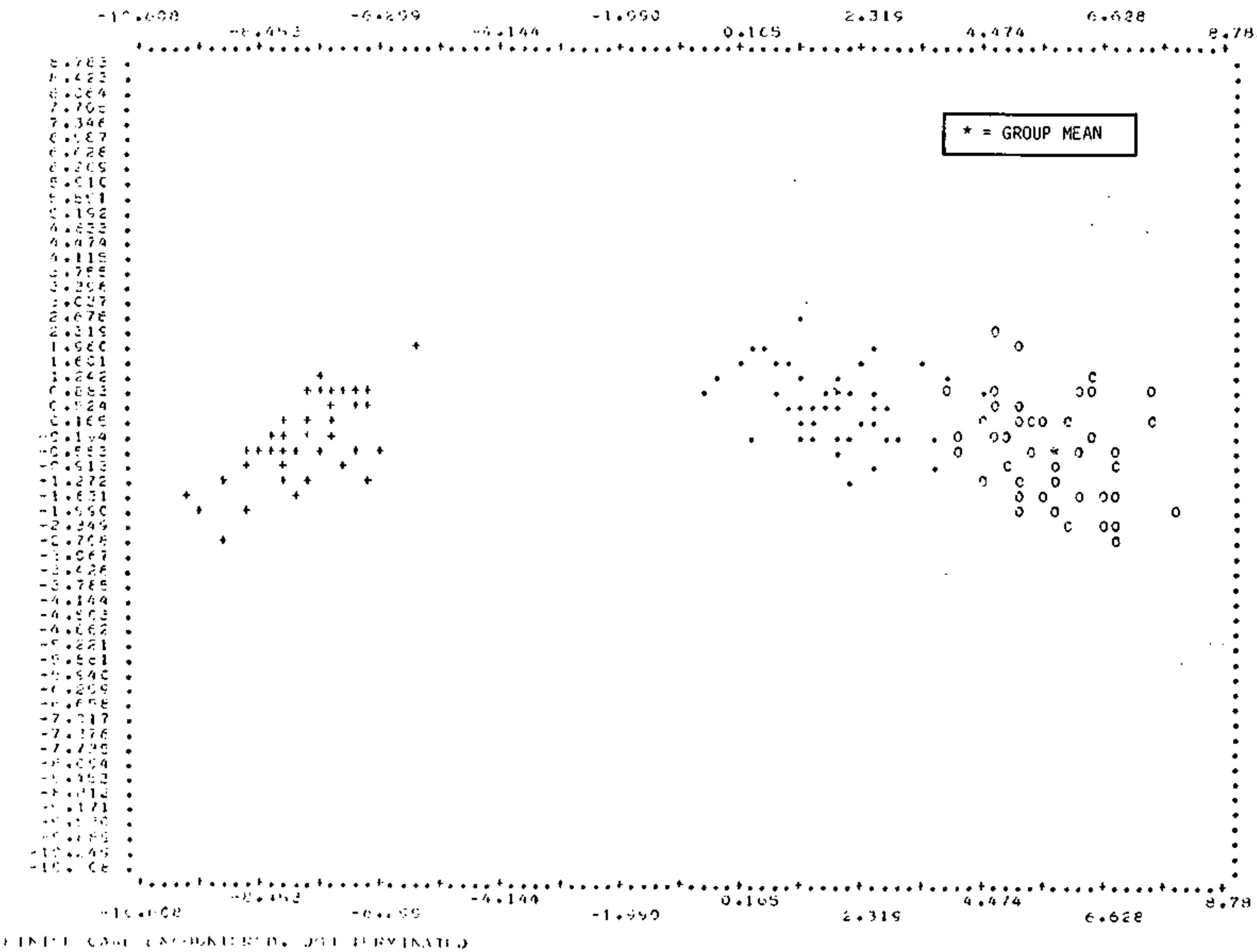


FIGURE 9. Scattergram illustrating near-perfect discrimination of cases into distinct regions or groups. Data is iris information gathered on 4 variables. (From Fisher, 1936, Annals of Eugenics).

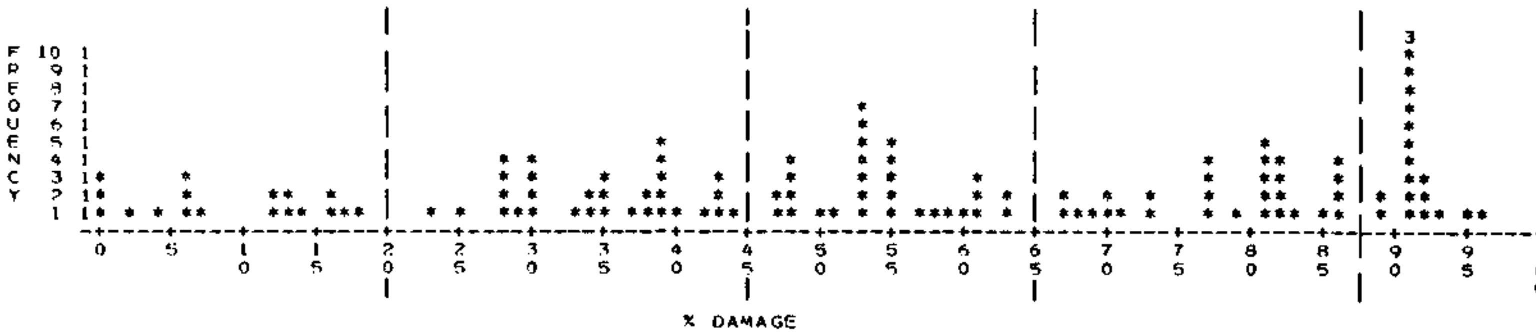
	Altitude	Film type	Crop type	Number of photographic variables	Number of Damage groups
1.	3000	IR	Beans	8	5
2.	3000	Color	Beans	8	5
3.	3000	IR	Corn	8	5
4.	3000	Color	Corn	8	5
5.	5000	IR	Beans	8	5
6.	5000	Color	Beans	8	5
7.	5000	IR	Corn	8	5
8.	5000	Color	Corn	8	5

The same procedure was followed for the three remaining types of crop damage (direct, plant or defoliation, and loss of yield due to stage) resulting in 32 (4 x 8) separate discriminant analyses. Four additional analyses were run in which the color and infrared variables were combined to form sixteen independent variables, using total damage as the dependent variable. Therefore, a total of 36 discriminant models were constructed and individually analyzed.

The approach to the quantitative analysis was straight-forward. First, the accumulated data for the 9 bean fields were classified into 5 various "natural" damage groups (0-20%, 20-45'%, 45-65%, 65-87%, 87-100%) for each of the 4 damage types, and the same was done for the 7 corn fields but using differing damage groups (0-5%, 5-25%, 25-45%, 45-65%, 65-100%). These groupings were done by examining a histogram of all the field points of each crop type (Figures 10 + 11) and dividing the data according to "naturally" occurring breaks. Although this is a subjective procedure, it is a better method than simply dividing the data into even groups (0-10%, 10-20%, 20-30%, etc.).

One bean field was not entered during the initial analysis, and then subsequently the data points were used as an unknown or test case to be classified into appropriate classes. The same was done for the data points in a corn test field.

Since an individual interpretation of all 36 discriminant analyses would be unnecessary and excessively long, 2 examples are presented herein. In all the analyses, the discriminant power of the models was poor as evidenced by the scattergrams for beans (Figure 12) and corn (Figure 13). No distinct clusters are evident as shown in the desired example of Fig. 9, but rather a continuum of observations is represented. This indicates that the various independent photographic variables, working in combination with one another, fail to differentiate the field observations into distinct groups. Despite this fact, the initial classification of all the known cases into appropriate groups was fair (Tables 9 and 10). For instance, in Table 9, there were 31 actual cases in the 20-45 percent classes and the model placed only 17 of the 31

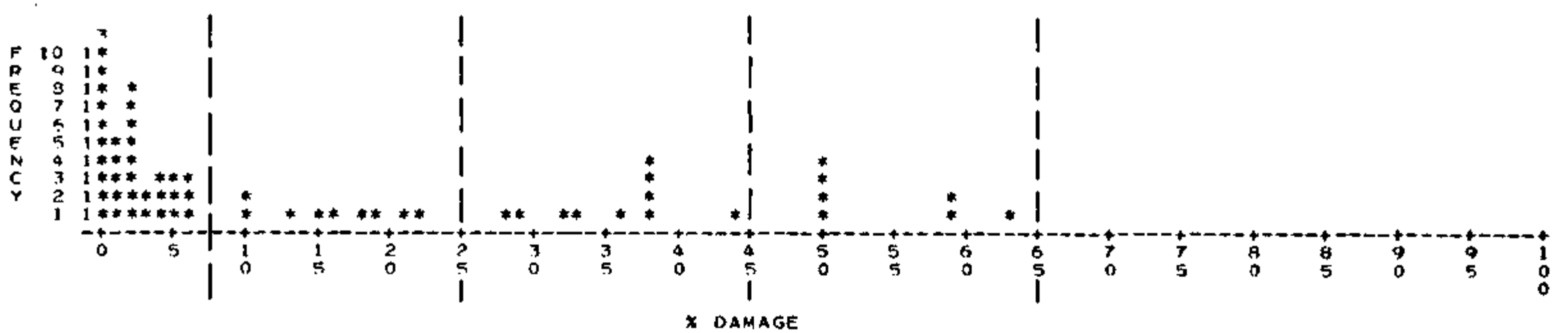


HISTOGRAM OF % DAMAGE FRFOUFNCIES

PERCENTAGE TOTAL LOSS

BEAN DATA SET MS FILM-3000 FT. ALTITUDE 9 FI ELDS-SADDORUS

FIGURE 10. Histogram of damage frequencies for the soybear. data set for the Sadorus storm. The vertical dashed lines indicate damage groups (0-20, 20-45, 45-65, 65-87, 87-100).



HISTOGRAM OF % DAMAGE FBEQUENCIES

PERCENTAGE TOTAL LOSS

CORN DATA SET IR FILM-3000 FT. ALTITUDE 7 FIELDS-SADDORUS

FIGURE 11. Histogram of damage frequencies for the corn data set for the Sadcrus storm. The vertical lines indicate damage groups (0-5, 5-25, 25-45, 45-65, 56-100).

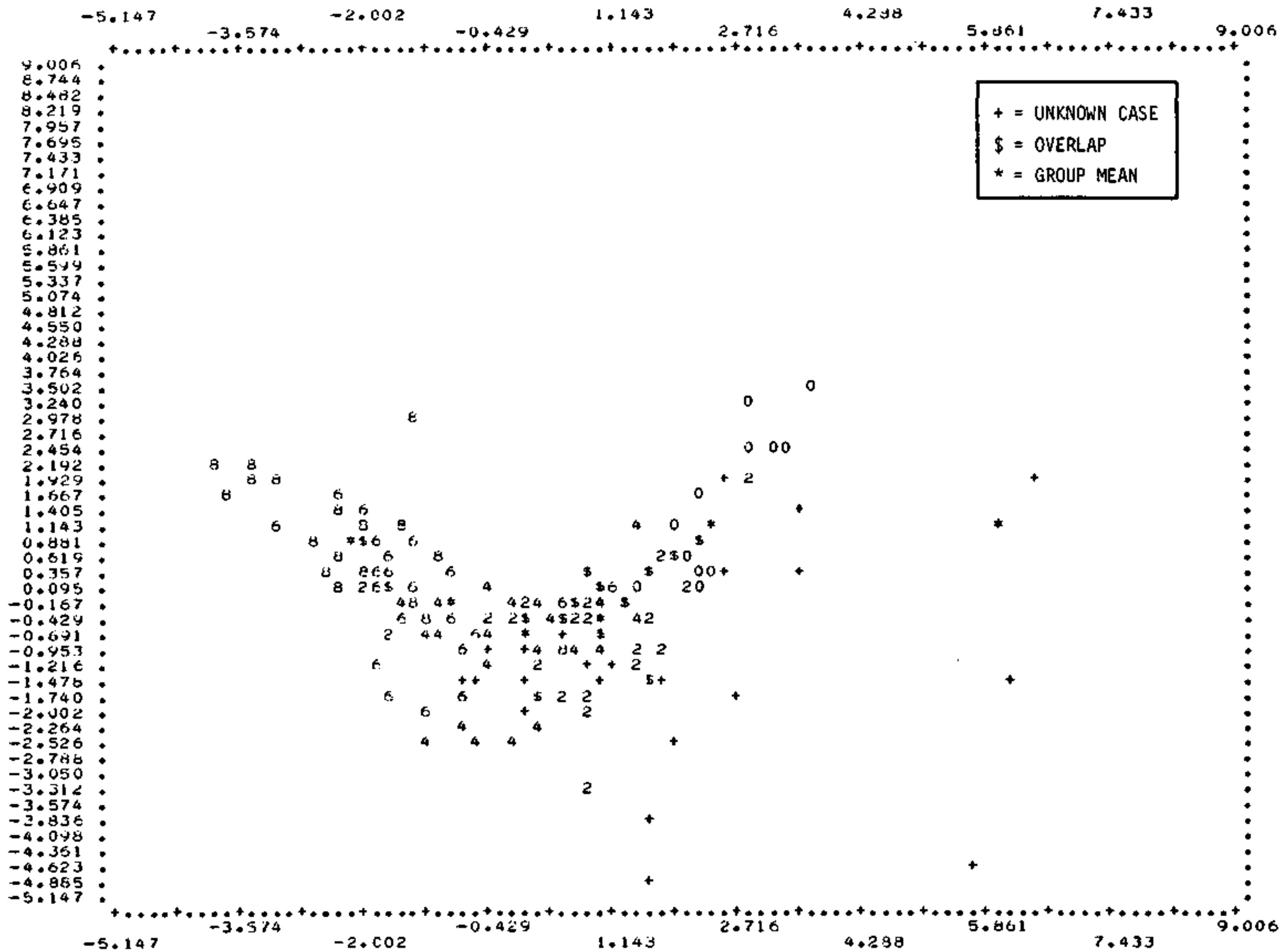


FIGURE 12. Scattergram of field data points for the bean data set. Numbers indicate the group into which a particular case is classified: 0—(0-20%), 2—(20-45%), 4—(45-65%), 6—(65-87%), 8—(87-100%).

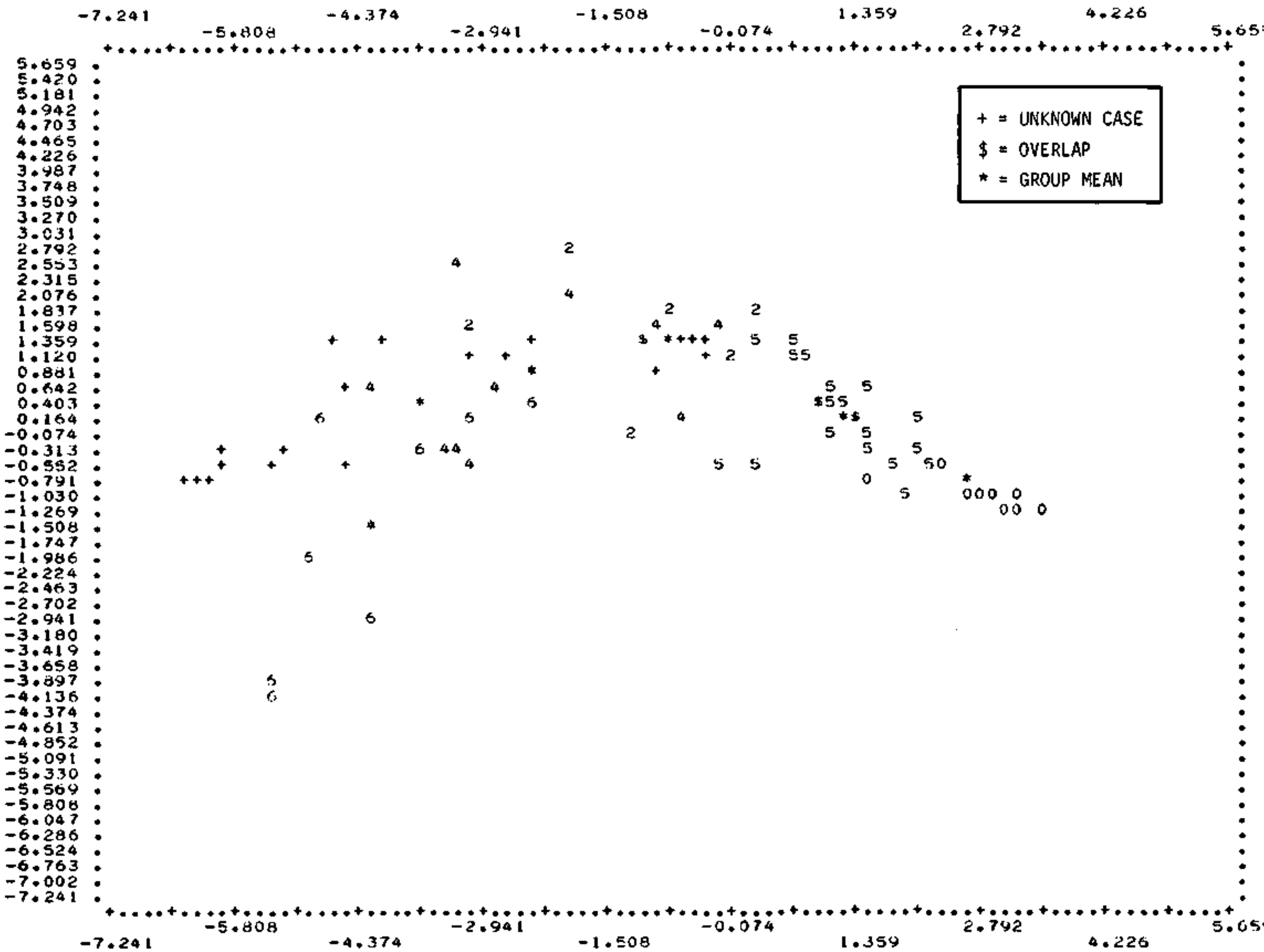


FIGURE 13. Scattergram of field data points for the corn data set. Numbers indicate the group into which a particular case is classified: 2—(0-5%), 5—(5-25%), 2—25-45%), 4—(45-65%, 6—(65-100%).

Table 9. Discriminant Analysis of Beans—Total Damage

Number of Actual Cases	Chosen Damage Classes	Number of Cases Classified into New Groups by Discriminant Model				
		0-20%	20-45%	45-65%	65-87%	87-100%
(18)	0-20%	14	4	0	0	0
(31)	20-45%	6	17	5	2	1
(29)	45-65%	1	10	13	5	0
(29)	65-87%	0	6	4	11	8
(21)	87-100%	0	0	1	4	16

Predictive Test Field

Chosen Damage Classes	0-20%	20-45%	45-65%	65-87%	87-100%
Number of Predicted Cases	11	15	6	0	0
Number of Actual Cases	12	13	7	0	0

Table 10. Discriminant Analysis of Corn—Defoliation Damage

Number of Actual Cases	Chosen Damage Classes	Number of Cases Classified into New Groups by Discriminant Model				
		0-5%	5-25%	25-45%	45-65%	65-100%
(13)	0-5%	11	2	0	0	0
(24)	5-25%	3	19	2	0	0
(8)	25-45%	0	1	4	3	0
(10)	45-65%	0	0	3	7	0
(8)	65-100%	0	0	0	3	5

Predictive Test Field

Chosen Damage Classes	0-5%	5-25%	25-45%	45-65%	65-100%
Number of Predicted Cases	0	0	7	5	10
Number of Actual Cases	1	0	5	7	9

values in the proper class. The remaining 14 values were placed in other classes. The diagonal lines in the tables bound the values that were placed into the correct class. However, when the model was used for prediction purposes on the test field, the results were poor.

There appears to be a good relationship between the predicted cases classified into each group according to the model and the actual number which should be present, according to the adjustors' data (bottom 2 rows of Tables 9 and 10). For instance, in Table 9 for the predictive test field, there were 12 actual cases in the 0-20% class and the model placed 11 values into that class. In reality, the classification of the test cases was poor. This can be demonstrated by listing the test (predicted) values with their actual actual value, arrayed in order of increasing damage (Table 11). If prediction were good with the discriminant model, the 2 columns would closely match. In actuality, they do not match. For instance, there were 12 actual values between 0-20% for "Beans ~ Total damage". The model placed only 4 values in the proper class. It even placed 4 values from the 45-65% class in the 0-20% class.

The overall results of the discriminant analysis for all 36 runs led to similar conclusions — the prediction capability of the discriminant models is not useful for purposes of predicting the patterns of percent damage.

C. Reasons for the Failure of Predictive Models.

There are 3 major reasons for the inability of the models to predict accurately. These are 1) the normally expected errors associated with the measurement of the densities on the film; 2) the lack of a good relationship between the ground truth (adjustor's damage values) and the measurements of recorded reflected radiation on the film and 3) the large amounts of noise introduced to the measurements via a changing soil color, varying darkness due to soil moisture, and other variable conditions.

Each of these reasons is discussed further below:

1. Densitometer analysis. Each time a sample is made of the aerial photography for red, green and blue (RGB) transmission densities, several problems could occur: These include:

   a. Inaccurate location of the point on the photograph where the adjustment was taken.

   b. The averaging effect of the spot size of the projected light in the densitometer ~ it covers an area on the ground much greater than that used for the actual adjustment.

   c. Control for lightning, different film emulsions, sun angle, etc. (hopefully controlled for by using ratio data).

2. Ground Truth. Adjustment necessarily is a method by which a prediction is made of the crop's ability to yield after hail damage. Hence, there is not necessarily a direct

Table 11. Classification of Unknown Data Points into Damage Groups.

Beans -- Total Damage

	Predicted Class*	Actual Class**
1	20-45%	0-20%
2	0-20%	
3	0-20%	
4	45-65%	
5	20-45%	
6	20-45%	
7	20-45%	
8	0-20%	
9	0-20%	
10	45-65%	
11	45-65%	
12	45-65%	0-20%
13	20-45%	20-45%
14	20-45%	
15	0-20%	
16	20-45%	
17	20-45%	
18	20-45%	
19	45-65%	
20	20-45%	
21	0-20%	
22	0-20%	
23	0-20%	
24	0-20%	
25	20-45%	20-45%
26	20-45%	45-65%
27	45-65%	
28	20-45%	
29	20-45%	
30	0-20%	
31	0-20%	
32	20-45%	45-65%

Corn -- Defoliation Damage

	Predicted Class*	Actual Class**
1	65-100%	0- 5%
2	45-65%	25-45%
3	24-45%	
4	65-100%	
5	45-65%	
6	45-65%	25-45%
7	65-100%	45-65%
8	24-45%	
9	65-100%	
10	25-45%	
11	45-65%	
12	45-65%	
13	65-100%	45-65%
14	25-45%	65-100%
15	25-45%	
16	25-45%	
17	25-45%	
18	65-100%	
19	65-100%	
20	65-100%	
21	65-100%	
22	65-100%	65-100%

* Classification of each data point according to the discriminate model.
**Classification based upon adjustors' data.

correspondence between the amount of physical damage and the loss of yield estimate. For example, a corn crop at a final growth stage may be subjected to considerable defoliation damage, but may yield a reasonable harvest while a crop at tassle stage with the same amount of defoliation has a considerable loss of yield. This considerable defoliation (indirect damage) would show up distinctly as heavy damage in a density analysis. Also, the actual final yield loss is made up of the direct and indirect damage. The aerial photography and subsequent density analyses can not distinguish between the two types of damage. The normal trend one would expect (and this does show up somewhat in the data) is that higher loss damages are associated with an increasing transmission density in the RGB bands and a decreasing density in the IR band. Perhaps the reason the models fail is the dependent variable (loss of yield) is not linearly associated with the independent variables consisting of density measurements.

3. Spatial Changes in Crops. Another major reason for the inability of the models to relate and predict is the different spatial arrangements of the crops before and after being subjected to hail damage. Because the density measurement is an averaging process, plant reflected radiation and radiation reflected by varying soil types including the changing reflecting properties of soils due to moisture, are all combined in a single transmission density value. Depending on the arrangements of the crop previous to and after the storm, more or less soil color may be incorporated into each reading. Before the storm, the effect could be assumed to be systematic ~ after the storm it would be unlikely that a systematic or constant amount of soil reflected radiation is incorporated in the density reading. Add to this the problems of varying soil types (color) and moisture (darkening) difference and the solution becomes exceedingly complex. Examination of two scattergrams (Figure 14) for the regression model or of the cluster plots (Figures 12 and 13) of the discriminant analysis bears this out. Figure 14 is a sample of scattergrams of densitometer measurements and total loss of yield. There are general trends that suggest a relationship between the same measurements and loss of yield; however, in both cases the percent loss of yield for any given densitometer reading will vary as much as 45-50 percent and can go as high as 90 percent. Scattergrams such as these were plotted for each storm for a variety of densitometer measurements and the result was similar (or worse) in all cases.

In both models prediction is impossible. The system is too noisy to allow for a reasonable estimate of damage.

Further studies will require considerable data processing to eliminate these problems. Future studies could include scanned data sets with the ability to separate out the background soil reflectances. This

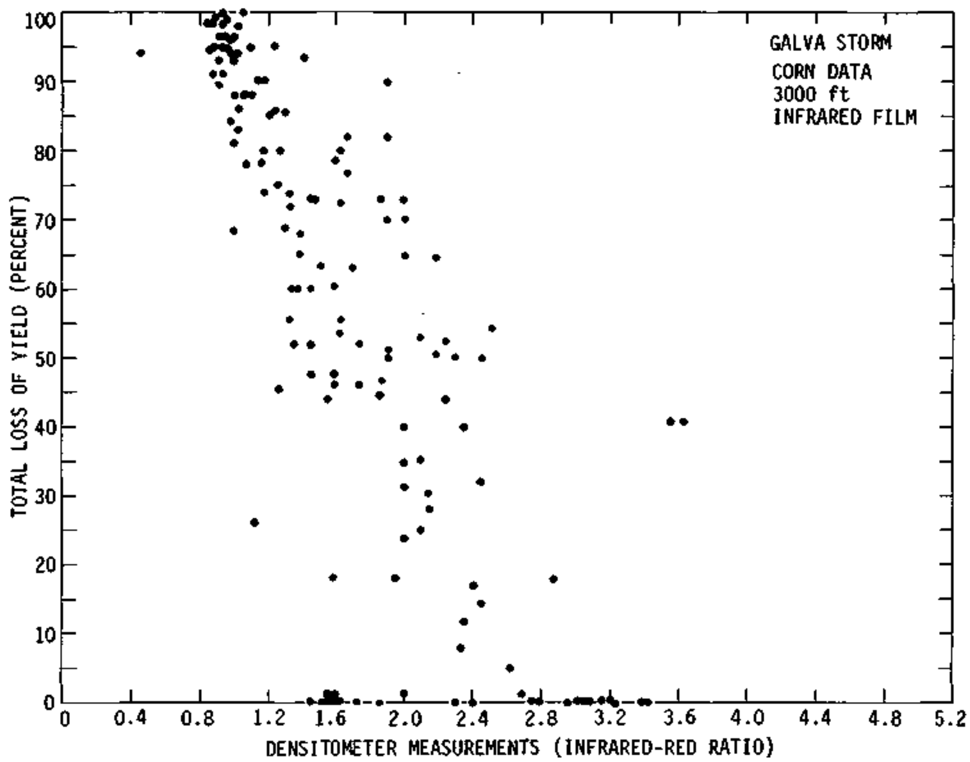


FIGURE 14a

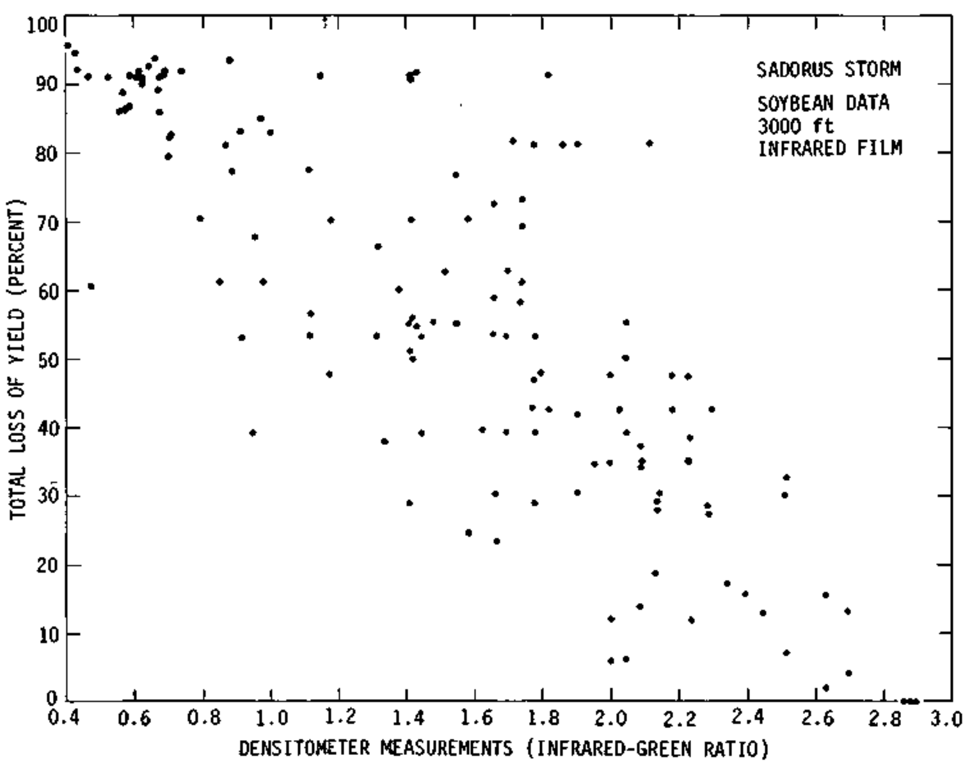


FIGURE 14b

Scattergram of densitometer measurements and percent loss of yield for a corn field (14a) at Galva and a soybean field (14b) at Sadorus.

would require use of multi-spectral film and analyses techniques. The development and operation of such a research program would be very expensive and could require as long as 5 years before any meaningful results were obtained. Any future program should include data sets of the ground collected hail damage estimates with emphasis on physical-structural damage which results in both a change in the reflectance and the geometry or the spatial arrangement of the individual plant. Complete control of each crop by stage, in the data processing steps, will be an absolute necessity.

D. An Alternative Independent Computer Mapping Approach.

1. A Description of the Computer Map

The problems of using remote sensing information to predict field damage represent only part of the total problem. Once this photographic or field information is obtained, it still needs to be put into map form, areas of loss aggregated, and a final field adjustment value determined. A computer mapping program was developed to meet these requirements.

With the failure of remote sensing data as a predictor, only the adjuster-determined points in each field were used as inputs in the mapping program. A modified version of the remote sensing mapping program (Figure 15) was created to accommodate adjuster's field points only. Several features of the program should be specifically indicated:

1. Map width is variable (maximum 13.0 inches) across the "lister" sheet. The map length (down the lister sheet) is automatically scaled along with centering of the map. This option allows flexibility in control of map size and appearance.

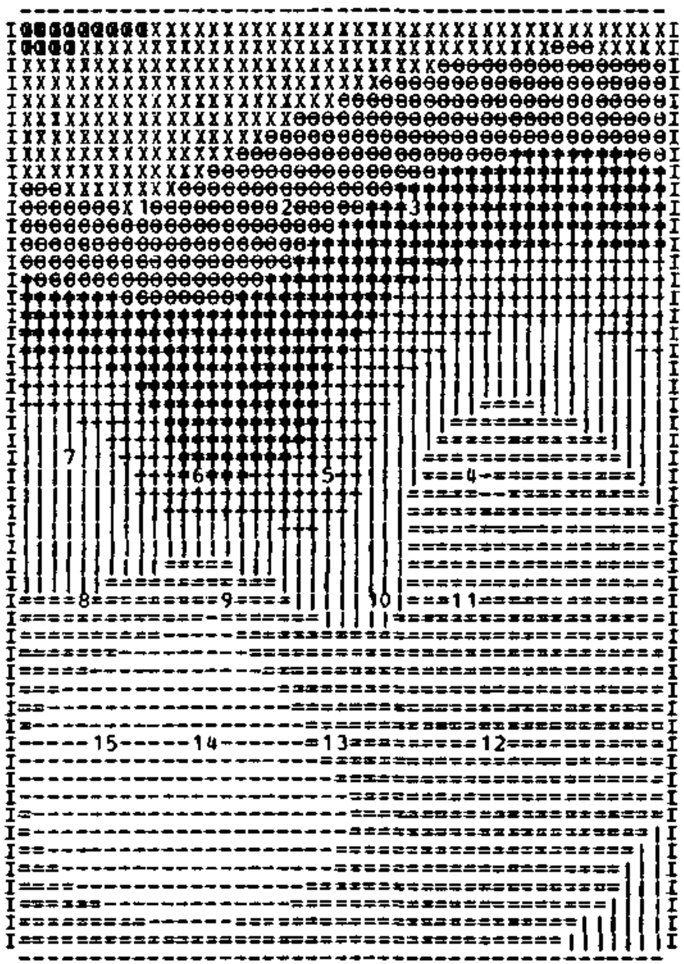
2. The adjuster's field points are numbered and automatically scaled to appear properly located in the map output.

3. The calculation of area by percent damage class is done by determining how many (frequency) map symbols fall into each class. This frequency represents a percentage of the area of the entire map area which is determined from the width, length, and scale variables.

4. The average of percent damage is based on the summation of all values of damage determined at each map point. The resulting sum is divided by the total number of map points to obtain the mean. For a square map (10.0 inches wide and long), the number of damage values, and hence map points, will be (13.0 inches x 10 cols/inch by 13.0 inches x 6 rows/inch) equals 130 x 78 or 10,140. The average percent damage is obtained by dividing the sum of the damage values by the sum of the damage points. The 78 rows occurs because of the 6 line printing per inch down the lister sheet (13.0 x 6 = 78 rows) as opposed to the 10 column printing across the lister sheet (13.0 x 10 - 130 columns).

FIELD MAPPING OF CHARLESTON HAIL STORM -- JULY 17, 1975

FIELD: C09
PHOTO: 7-018
ALTIMETER: 3000
FILM TYPE: MS
SCALE: 1"= 530.1
CROP: CORN
CROP STAGE: TASS
NO OBS: 15
XMIN: 0.0
XMAX: 2.50
YMIN: 0.0
YMAX: 3.60



SYMBOL	CLASS (% DAMAGE)	FREQUENCY (%)	AREA (ACRES)
	0- 10	0.0	0.0
---	10- 20	12.22	7.10
===	20- 30	32.18	18.68
|||	30- 40	11.97	6.95
+++	40- 50	8.80	5.11
‡‡‡	50- 60	12.82	7.44
θθθ	60- 70	11.88	6.90
XXX	70- 80	9.57	5.56
▪▪▪	80- 90	0.56	0.32
●●●	90-100	0.0	0.0

58.06 = TOTAL ACREAGE

X-COORDINATE	Y-COORDINATE
0.43	0.72
1.04	0.73
1.54	0.73
1.75	1.73
1.17	1.73
0.69	1.72
0.18	1.70
0.22	2.21
0.77	2.22
1.36	2.23
1.73	2.23
1.82	2.81
1.18	2.81
0.66	2.80
0.27	2.79

Z-VALUE
70.00
63.00
57.00
19.00
48.00
55.00
31.00
31.00
21.00
36.00
21.00
21.00
21.00
11.00
13.00

AVERAGE OF % DAMAGE FOB ENTIRE FIELD BASED ON ALL EVALUATED HAP POINTS= 40.12 %

INSURED VALUE OF EACH ACRF= $200.00

TOTAL ADJUSTMENT= $ 4658.54

FIGURE 15. Computer map and accompanying loss statistics for a hail damaged field.

5. The total adjustment simply equals:

$$\frac{\text{Insured value per acre X Total acreage X Average \% of damage}}{100}$$

A listing of the program and instructions for running the program appears in Appendix A.

2. Testing of Sample Sizes and Methods

The number of points adjusted in each field for this research project (averaging 6 to 16 points per field and as high as 32 points per field) would not be possible within the normal routine of adjusting. A study using the mapping technique was made of the errors obtained using 8, 6, and 4 point sampling from fields of 8 or greater adjusted points from the entire hail damage data set for the summer of 1975 which produced a useable data set of 21 bean fields and 23 corn fields. The purpose of this study was to obtain preliminary information on the number of points, or sampling techniques, necessary to obtain an accurate estimate of the loss of yield for the <u>entire</u> field.

The steps in the mapping analysis were as follows:

1. A map was made of each field using all the adjuster's data points for the field. The average percent was recorded.

2. Each field was re-sampled for 8, 6, and 4 points in the following fashion:

   a. A systematic sample and a surface fit (map) was made to estimate average percent damage. This method is called SYST (SURF). The systematic sampling was generally one of either 3 configurations based on the number of points (Figure 16).

   b. Photographically determined location of 8, 6, and 4 point samples based on the visual inspection of the IR aerial photographs of each field. The points chosen were subjectively obtained and thought to be "representative" points. These points were then surfaced (mapped) to determine the average loss. This method is called PHOTO (SURF).

   c. A simple average was calculated of the 8, 6, or 4 points for the same points used in "b". This method is called PHOTO (AVG).

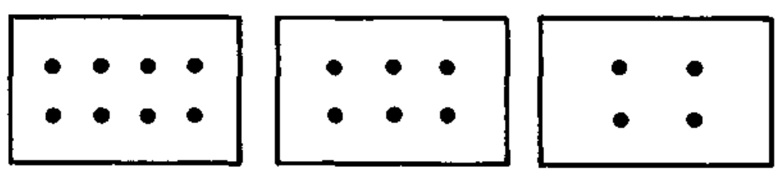


FIGURE 16. Systematic sampling configurations

3. The differences between the average percent damage obtained by the above 3 methods (a, b, c) and the average percent damage obtained from the surfaced maps of all points was calculated for each field by crop type. Table 12 shows one example of all the bean fields 8-point systematically obtained samples differenced from the average percent damage obtained from a map of all the data points. The column of data marked DIFFERENCE is then subjected to statistical analyses which produces a table of standard descriptive statistics.

Table 12. Example of all the Bean Fields 8 Point Systematically Obtained Samples Differenced From the Average Loss Obtained from a Map of all the Points. Calculated Statistics also Appear.

Field	Points	All % Damage	Sample % Damage	Difference
S03	16	38.6	38.5	0.1
S07	17	59.3	55.0	4.3
S09	8	47.3	47.3	0.0
S11	8	44.9	44.9	0.0
S13	8	91.6	91.6	0.0
S14	24	51.0	54.1	-3.1
S15	13	90.6	90.2	0.4
S17a	17	58.7	61.1	-2.4
S17b	17	60.0	63.4	-3.4
D16	11	64.8	64.6	0.2
C12	8	42.7	42.7	0.0
C14	8	34.8	34.8	0.0
C18	13	79.0	82.2	-3.2
C20	12	80.8	78.0	2.8
C22	10	90.5	89.8	0.7
C23	8	95.4	95.4	0.0
C24	29	87.7	90.4	-2.7
G08	9	97.0	96.9	0.1
G13	14	71.7	72.0	-0.3
G14	12	47.7	46.2	1.5
G18	9	97.0	97.0	0.0
G19	14	90.2	90.3	-0.1

Statistic	Value	Standard Error	z or t Test
Mean	-0.2318	0.3998	
Std. Dev.	1.8322	0.2827	
Skewness	-0.2395	0.4910	-0.4877
Kurtosis	0.7528	0.9528	0.7901

Sample size (N) = 22

Significance level = 5%, 1.96 standard deviation units

4. Summaries of all of these runs by crop type appear in Table 13. The statistical formulae used for this test are shown in Table 14.

   Ideally, for each sampling method and for the samples of differing number of points of the differences, the mean (x) should be zero and the standard deviation (a) as small as possible. These conditions would indicate a series of average percent damages close to those obtained by using all of the data points evaluated by the adjusters.

   Examination of both tables shows that this ideal does not exist. Generally, the 8-point systematic sample [SYST (SURF)] has a smaller mean deviation from zero and the smaller standard deviation than the 6-point or 4-point values. This is borne out by Figures 17, 18, and 19 which show all of the data in graphical form.

   A means difference test between all pairs of data (8-6, 8-4, 6-4) of point samples for all sampling methods will show no significant difference in the great majority of cases. In addition, each mean (x) can be shown to be statistically equal to zero. The conclusion of this study shows than no clear method, or number of points, can be shown to be statistically better than any other. An alternate test is needed.

5. In place of a "means difference test" to evaluate the effect of the number of sample points used to determine the average percent damage of a field, a "standard deviation difference" test can be employed. Essentially it is concluded that the error due to differencing respective average percent damages is cancelled and can be assumed to equal zero. The only statistic that can be tested to see if there is a difference between the average percent damages derived using a differing number of data points (8, 6, 4) is the measure of dispersion (a) or spread of the average percent damages about the mean. A standard deviation difference test can be used for this purpose. The statistical formulae used in this test are shown in Table 14. The results of the tests for the corn and bean fields are shown in Tables 15 and 16.

   The objective in using the standard deviation difference tests is to find the sample number of points with which it has the least dispersion or standard deviation (and hence reduces the error) and is significantly different (reject Ho) from the number of points. Examination of Tables 15 and 16 shows the 8-point map sample to have the least amount of dispersion for all sampling methods. If the 8-point samples are significantly different than the 6- or 4-point samples, then the 8-point sample would be clearly the better sample size.

   Table 15 shows the results of the standard deviation difference test for the corn. The 8-point sample <u>is</u>

Table 13. Corn and Bean Error Data Summary for Various Numbers of Sampling Points and Sampling Methods

Corn Error Data Summary

	Error Measure	All Vs 8				All Vs 6				All Vs 4			
	Statistic	$\bar{x}$	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$	$\bar{x}$	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$	$\bar{x}$	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$
SAMPLING METHOD	SYST(SURF)	0.1800	1.0054	.2052	.1451	.2920	2.4744	.5051	.3572	1.1280	4.1566	.8485	.6000
	PHOTO(SURF)	-1.3720	4.1332	.8812	.6231	-1.0435	2.5869	.5515	.3900	-.9296	4.1566	.9937	.7026
	PHOTO(AVG)	- .4478	2.3510	.5012	.3544	- .0478	3.2498	.6929	.4899	.3739	5.8304	1.2430	.8790

Beans Error Data Summary

	Error Measure	All Vs 8				All Vs 6				All Vs 4			
	Statistic	x	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$	x	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$	x	σ	$\sigma_{\bar{x}}$	$\sigma_{\bar{\sigma}}$
SAMPLING METHOD	SYST(SURF)	- .2318	1.8322	.3998	.2827	- .7409	4.5944	1.0026	.7089	-.1500	6.1159	1.3346	.9437
	PHOTO(SURF)	- .7286	2.7722	.6199	.4383	-1.3467	3.6983	.8270	.5848	-.3209	5.2175	1.1667	.8250
	PHOTO(AVG)	.2524	2.8946	.6472	.4577	1.1619	5.4402	1.2165	.8602	-.1476	8.3837	1.8746	1.3256

$\bar{x}$ --Mean of Differences

$\bar{\sigma}$ --Standard Deviation

$\sigma_{\bar{\sigma}}$ --Standard Error of Mean

σ_{σ} --Standard Error of Standard Deviation

Table 14. Formulae for Statistics used in Data Table

Mean ($\bar{x}$):

$$x = \frac{\Sigma X}{N}$$

where: X = an observation value
N = total number of observations
Σ = sigma notation with $\sum_{j=1}^{N}$ assumed counter

Standard Deviation (a):

(sample) $$\sigma_s = \sqrt{\frac{\Sigma X^2}{N} - \frac{\Sigma X}{N}^2}$$

(population estimate) $$\hat{\sigma}_p = \sigma s X \sqrt{\frac{N}{N-1}}$$

Standard Error of the Mean ($\sigma_{\overline{X}}$):

$$\sigma_{\overline{X}} = \frac{\hat{\sigma}_p}{\sqrt{N}}$$

Standard Error of the Standard Deviation (σ_σ):

$$\sigma_\sigma = \frac{\hat{\sigma}_p}{\sqrt{2N}}$$

Unpooled Estimate of the Standard Error of the Difference of Standard Deviations ($\sigma_{\sigma - \overline{\sigma}}$):

$$\sigma_{\sigma - \overline{\sigma}} = \sqrt{\sigma_{\sigma_1}^{\ 2} + \sigma_{\sigma_2}^{\ 2}}$$

where the standard error of the standard deviations (σ_{σ_1} and σ_{σ_2}) are derived from independent samples.

t-Statistic for Standard Deviations Difference Test:

$$t = \frac{\sigma_{s1} - \sigma_{s2}}{\sqrt{\sigma_{\sigma_1}^{\ 2} + \sigma_{\sigma_2}^{\ 2}}}$$

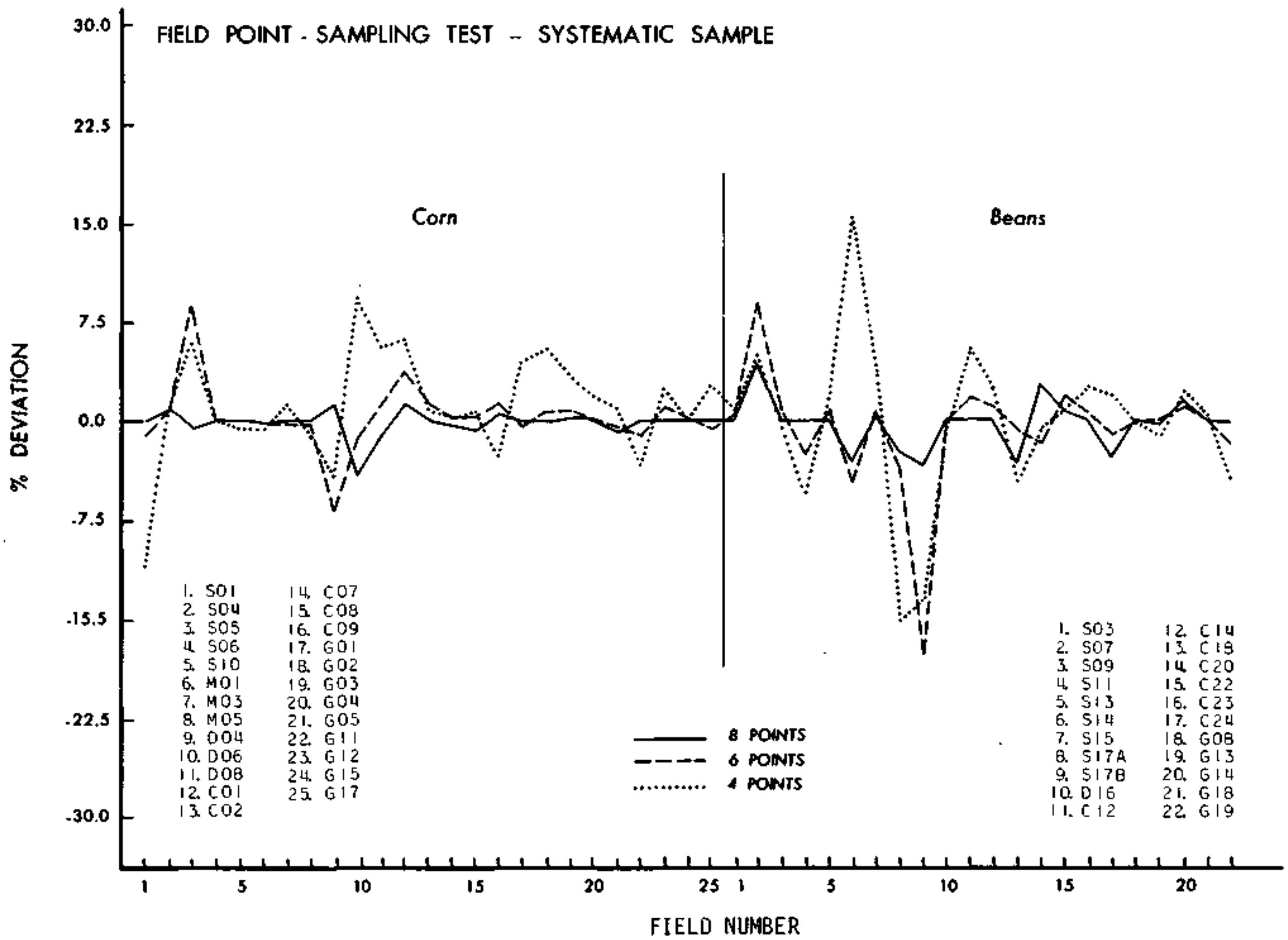


FIGURE 17. Graphical results of the standard deviation difference test for 4, 6, and 8 points for the systematic sample.

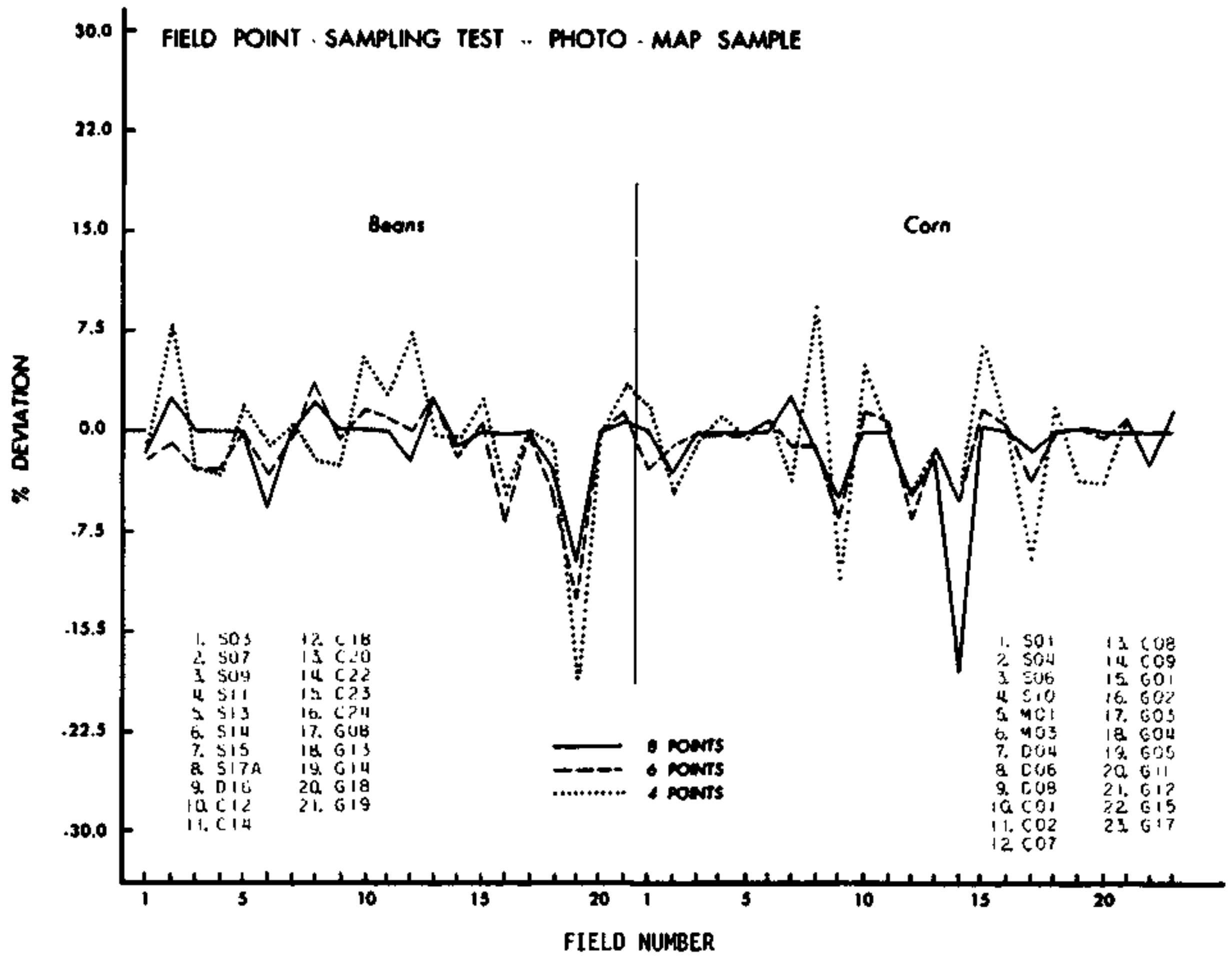


FIGURE 18. Graphical results of the standard deviation difference test for 4, 6, and 8 points for the photo-map sample.

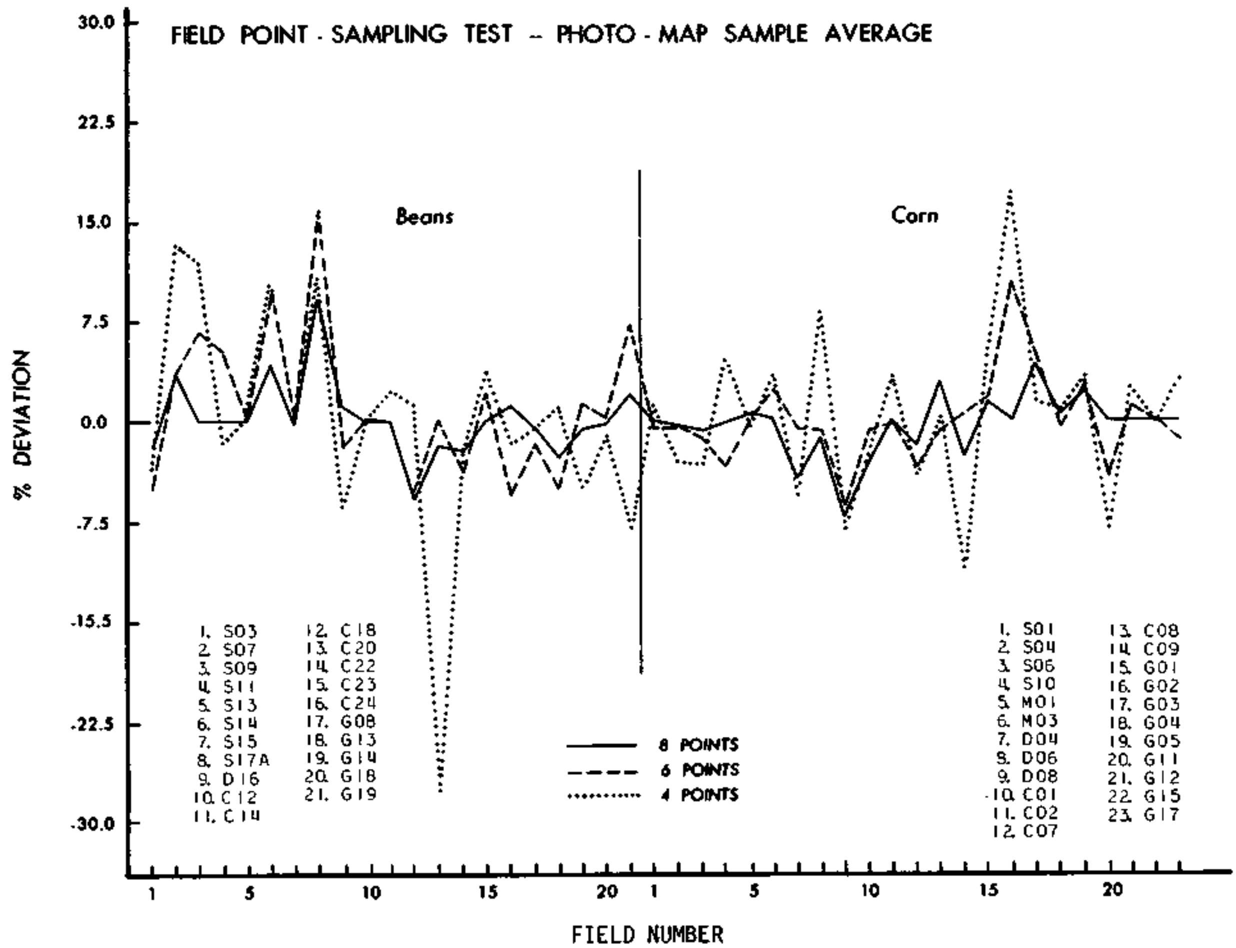


FIGURE 19. Graphical results of the standard deviation difference test for 4, 6, and 8 points for photo-map sample average.

Table 15. Corn-Standard Deviations Difference t-Test: Number Points

Ho: $(\sigma_{s_1} - \sigma_{s_2}) - (\sigma_{p_1} - \sigma_{p_2}) = 0$

	Samples	Std. Dev. Difference	Unpooled Std. Error	t	Reject Ho?
SYST (SURF)	8 points--6 points	1.4690	.3855	3.8106	YES
	8 points--4 points	3.1512	.6173	5.1048	YES
	6 points--4 points	1.6822	.6983	2.4090	YES
PHOTO (SURF)	8 points--6 points	1.5463	.7351	2.1035	YES
	8 points--4 points	.0234	.9391	0.0249	NO
	6 points--4 points	1.5697	.8036	1.9533	NO
PHOTO (AVG)	8 points--6 points	.8988	.6046	1.4866	NO
	8 points--4 points	3.4794	.9478	3.6710	YES
	6 points--4 points	2.5806	1.006	2.565	YES

$N_1 = N_2 = 23$

D.F. $= N_1 + N_2 - 2 = 44$

t-Table at .05 significance level and 44 D.F. = 2.02

Table 16. Beans-Standard Deviations Difference t-Test: Number Points

Ho: $(\sigma_{s_1} - \sigma_{s_2}) - (\sigma_{p_1} - \sigma_{p_2}) = 0$

	Samples	Std. Dev. Difference	Unpooled Std. Error	t	Reject Ho?
SYST (SURF)	8 points--6 points	2.7622	.7632	3.6192	YES
	8 points--4 points	4.2837	.9851	4.3485	YES
	6 points--4 points	1.5215	1.1803	1.2891	NO
PHOTO (SURF)	8 points--6 points	.9261	.7308	1.2672	NO
	8 points--4 points	2.4453	.9342	2.617	YES
	6 points--4 points	1.5192	1.011	1.5027	NO
PHOTO (AVG)	8 points--6 points	2.5456	.9744	2.6125	YES
	8 points--4ppoints	5.4891	1.4024	3.9141	YES
	6 points--4 points	2.9435	1.5802	1.8627	NO

$N_1 = N_2 = 21$

D.F. = $N_1 + N_2 - 2 = 40$

t-Table at .05 significance and 40 D.F. = 2.02

significantly different from the 6- and 4-point samples with the exception of the PHOTO (SURF) sampling 8-4 points and the PHOTO (AVG) sampling 8-6 points. However, in both of these cases, the standard deviations of the respective samples (Table 13) were considerably greater than the similar size samples of the SYST (SURF) sampling. It is doubtful that these 2 exceptions indicate that the "PHOTO assisted" method of sampling improved the map accuracy. A test to determine significance difference in sampling method was carried out in Step 6.

Similar results were obtained for the beans (Table 13). With only one exception, the 8-point samples were significantly different than the 6- or 4-point samples. In addition to the tests of the 8-point samples, as compared to the 6-point and 4-point samples, an additional test was carried out to determine if there was any difference between the 6-point and the 4-point sample. If no difference (cannot reject Ho) exists, then this would be further confirmation that the 8-point sample is distinctly different than the 6- or 4-point sample which would appear to have about the same effect. In Table 15 for the corn, only the PHOTO (SURF) shows no difference between the 6 and 4 point samples. For the beans (Table 16) all sampling methods show no difference between the 6 and 4 point samples. There appears to be a distinctive difference in the error variability by crop type. The standard deviations for the beans (Table 12) are generally higher than for the corn (Table 13). No tests were done comparing the sampling by crop type but this would probably be warranted in further studies.

6. A similar testing procedure to the one in Step 5 was used to compare the sampling methods rather than the number of points. For this test only the 8-point samples were used and a comparison was made of the sampling methods by crop type. The results are shown in Tables 17 and 18 and present an interesting dichotomy. The tests for the corn show that each method is significantly different than any other. The best method would still be the one which produces the least error dispersion and from Table 12 this has been shown to be the SYST (SURF).

   The tests for the beans show no method of sampling is significantly different than any other method. However, the first 2 tests show t scores of 1.8021 and 1.9747 which indicate a tendency for these methods to be different. Again variability in errors of the maps, adjustment and hail damage patterns by crop type need to be further explored.

The basic conclusion from the mapping analysis is that an 8-point systematic sample is the minimum sample size and method necessary to determine a reasonable map of hail damage patterns from adjustment field

Table 17. Corn-Standard Deviation Difference t-Test: Sampling Method (8-point sample only)

Ho: $(\sigma_{s_1} - \sigma_{s_2}) - (\sigma_{p_1} - \sigma_{p_2}) = 0$

Samples	Std. Dev. Difference	Unpooled Std. Error	t	Reject Ho?
SYST(SURF) - PHOTO(SURF)	3.1278	.6398	4.8887	YES
SYST(SURF) - PHOTO(AVG)	1.3456	.3829	3.5114	YES
PHOTO(SURF) - PHOTO(AVG)	1.7822	.7168	2.4863	YES

$N_1 = N_2 = 23$

D.F. = $N_1 + N_2 - 2 = 44$

t-Table at .05 significance level and 44 D.F. = 2.02

Table 18. Beans-Standard Deviation Difference t-Test: Sampling Method (8-point samples only)

Ho: $(\sigma_{s_1} - \sigma_{s_2}) - (\sigma_{p_1} - \sigma_{p_2}) = 0$

Samples	Std. Dev. Difference	Unpooled Std. Error	t	Reject Ho?
SYST(SURF) - PHOTO(SURF)	.9400	.5216	1.8021	NO
SYST(SURF) - PHOTO(AVG)	1.0624	.5380	1.9747	NO
PHOTO(SURF) - PHOTO(AVG)	.1224	.6337	0.1931	NO

$N_1 = N_2 = 21$

D.F. = $N_1 + N_2 - 2 = 40$

t-Table at .05 significance and 40 D.F. = 2.02

values. There appears to be a bias introduced according to crop type and this should be further explored. Perhaps crop stage may also be as important a variable to the mapping as it appears to be for remote sensing analysis.

The research into the best sampling method, sample size, and mapping of the results is the main objective of the May 1976-May 1977 research. Many of the problems mentioned here will be investigated along with other aspects of computer mapping.

6. ADJUSTER USE OF AERIAL PHOTOGRAPHY

The secondary objective of this research, use of aerial photographs to delineate severe hail damage areas, has been satisfied. Selected adjusters will be using aerial photographs during the hail season of 1976 to aid them in their normal adjusting procedures. A substantial effort, beginning in July 1975, was necessary to fulfill the goal.

After working with aerial photography for the purpose of detecting hail damage to crops for two growing seasons, the ISWS staff and Country Companies adjusters were convinced that crop damage caused by hail yielded an image which could consistently be identified by visual inspection of the aerial photographs. The project adjusters had decided that the photography was helpful to them in the field to the extent that they preferred examining aerial photographs prior to beginning their adjustments.

On July 12, 1975, a hailstorm occurred southwest of Sadorus (description given earlier in report), approximately ten miles from Champaign where the ISWS offices are located. The severe storm was small enough to photograph almost the entire storm. The stages of the crops were considered optimum for detection of hail damage. A pilot project was formulated to allow specially selected adjusters to use the aerial photography as an aid in their final adjustments. The purposes of the project were 1) to familiarize these adjusters with the types of film used in the project and to teach them how to distinguish crop hail damage from other images in the film, 2) the utility of the photography could be determined in an actual use situation and, 3) the adjusters reactions to using the photography were sought.

In preparation for the study contact prints were made of all the transparencies taken. Mosaics of the 12,000 ft and the 5,000 ft AGL photographs were made. The 12,000 ft mosaics gave a generalized view of the storm. The 5,000 ft mosaic offered a more detailed view of the storm area southwest of Sadorus. This scale photography allowed for easier identification of a field while still keeping it in the context of its surroundings. The 3,000 ft photography allowed for a detailed look at fields near the center of the storm area. These photographs were numbered and their locations identified on a plat map for the adjustors reference.

The mosaics and photography were taken to the storm center in Champaign on August 11, 1975. The adjusters were familiarized with the project, and the photography, by project staff members. The ISWS staff were then available throughout the adjusting period for consultation. A questionaire was given to each of the adjusters at the end of the adjusting period. The survey was designed to extract the adjusters' opinions of the process, problems encountered, and suggestions of how to improve photography.

The results of this experiment offered valuable information for formulating a plan for the use of aerial photography in hail-crop adjusting. The responses to the questionnaire indicated that the adjusters had a strong preference for the infrared false color photography, mainly because of its high contrast characteristics. The adjusters preferred the smaller scale photographs, both 12,000 ft and 5,000 ft, because particular fields were in context with the surrounding area; and there was enough detail at the 5,000 ft level for accurate identification of hail patterns and landmarks. The photographs were advantageous in dividing a field into heavy, medium, and light damage areas, in estimating acreage more accurately, in distinguishing heavy and light loss areas, in identifying irregularly shaped fields, in aiding map drawing, and in showing hail areas which might otherwise be missed. Other advantages of the use of aerial photography would be in public relations, gaining the confidence of the insured, as a record when settling snags, and hopefully, eliminating potential call backs. The adjusters felt that they took more counts than usual, and that hail damage areas were easily identifiable except for damage lighter than 10-20%. Problems found when using the photographs were the adjusters' lack of both experience and familiarity with the photography, darkened edges on pictures, and the fact that pictures don't show crop recovery variables.

The enthusiasm of the adjusters and general success of the pilot program indicated that aerial photographs could be used to aid adjusters in the performance of their normal duties. Therefore, a meeting was held in late November 1975 to outline an aerial photography use program to certain Country Companies staff members.

In general, it was felt that use of the photographs would improve the efficiency and accuracy of the hail adjusters and provide a better service to various farm bureau agencies. Specific benefits that could possibly be obtained from 5,000 and 12,000 ft AGL photography were:

1. Isoline definition of damage (light, medium, heavy) would be an aid for auditing claims. Settlement percentages would be recorded on an overlay of the photographs or on a map and any unusual payment would be evident and might merit re-inspection.

2. The liability to the company for a given storm could be approximated. Insured farms could be identified on the photographs and the number of acres in each damage category for all the farms estimated.

3. An estimation of the extent of the damage areas would allow supervisors to efficiently use their personnel. Knowledge of approximate damage areas would allow estimation of the number of adjusters needed.

4. The photographs provide a permanent record that might be beneficially used as an aid in disputes that may arise after the crop was harvested.

5. Use of the photographs would possibly increase confidence and credibility with the insured. Farmers as a group are receptive to new technology, and some discussion with farmers about the photographs indicated they would accept aerial photography as an aid to the adjuster.

6. Working copies of photographs supplied to the adjuster would increase his accuracy. He could accurately measure areas that are now estimated ~ this estimation can be difficult and many times inaccurate.

7. The photographs would help prevent "call-backs" due to faulty examination during the first visit. Classified ranges of damages for individual fields would prevent surprises for the adjuster as he moved from field to field and from farm to farm. The photographs would likely increase consultation and discussion between the adjuster and insured. This would leave the insured with a feeling of being well informed and fairly treated. He would be less likely to "call-back".

8. If the photographs indicated wide variability of damage in a field more measurements would need to be taken. On the other hand, consistent or light damage across a field would indicate that fewer measurements could be taken.

9. Water spots could be identified and deleted from payment, if desired.

10. Slides of damaged fields would serve as a great aid for evening consultation between adjusters and supervisors.

After considering the potential benefits of the photographs, a second meeting was requested to determine the cost of forming an Aerial Survey Department. This cost included permanent or capital items (such as cameras, copy stand, light table, etc.) and expendables or consumable items for 1 year of aerial photography of 140 square miles. Capital costs were $1570 and expendables were $5780 for a total of $7530. The majority ($3900) of the expendable cost was for aerial photography service.

The decision to form the Aerial Survey Department was made in January 1976. The operational plan of the Department was to begin obtaining infrared aerial photographs during the summer of 1976. The transparencies from the aerial photography would be rephotographed and 5 x 5 prints supplied to certain adjusters for their use in the crop adjusting. However, before this could happen the adjusters had to be trained to interpret and use the photography for more accurate loss assessments.

Preparation for the training program began in February. The primary task was to prepare an Aerial Photography Handbook for Country Companies Crop-Hail Adjusters. The 33 page handbook was designed to acquaint the adjusters with use of the photographs and included examples of infrared photographs, an introduction of the elements of photographic interpretation, and a section of how to determine area (in acres) from the photography.

Two training sessions took place for the 25 adjusters on March 23 and 24. Included in this 2-day session were 2 half day sessions when the adjusters were acquainted with use of the photographs. The training was done by ISWS staff members and the 2 crop adjusters who had worked with the photographs in 1974 and 1975.

The formation of the Aerial Survey Department and the use of techniques developed by this research should be considered as positive fulfillment of one of the objectives of the project. These techniques should help attain more accurate loss settlements for many years.

7. SUMMARY AND RECOMMENDATIONS

The two objectives of this project were: 1) to investigate the application and potential accuracy of using aerial photography to assess hail damage to Illinois' primary crops; and 2) to investigate the use of aerial photography as a means to delineate severe crop damage as an aid in directing and performing storm surveying.

The first objective focused on developing an ability to better quantify losses within a particular field or area based on statistical analyses of the aerial photographs calibrated with selected field assessments. It was hoped that a more accurate, as well as an inexpensive, technique for assessing losses could be devised. The second objective dealt with developing methods by which crop hail adjusters could use the aerial photographs for improving standard crop adjusting procedures. Comparable photographic data and field loss data were needed for the analyses to satisfy both objectives.

The May 1975-April 1976 study was expanded over the May 1974-75 period to include more field loss assessments and to include the use of false color infrared film which was believed to offer the potential for better results than natural color film. Good field and aerial photography data were collected on six major storms in Illinois. Nearly 1,000 surface loss assessments were made by two adjusters provided to the project by the Country Companies, and over 800 aerial photographs were obtained for the study by employing a commercial photographic firm.

Extensive, sophisticated analyses were performed on all of the data. The final result is that accurate quantification of field losses using aerial photographs is not possible. The three basic reasons for this failure are: 1) errors associated with the measurements of film dye densities on the film; 2) the lack of a good relationship between the field calibration assessment (loss of yield measurements) and the measurement recorded, reflected radiation on the film (in the film dyes); and 3) large variations to the reflected radiation measurements due to varying soil color, moisture differences, crop variety differences, and differing farm practices which confuse the discernment of the hail damage. The second and third reasons are most critical.

Further pursuit of the quantification of field losses with aerial photography will require considerable data processing to eliminate the problems mentioned. This could include scanned data sets (complete scanning of the film) with the ability to separate out the background soil reflectances. This would require use of multi-spectral film and analyses techniques. The development and operation of such a research program would be very expensive and could require as long as five years before any meaningful results were obtained. Any future program should place emphasis on physical-structural damage which results in the change in reflectance of the plants. The combination of direct and indirect damage to obtain a final yield loss is a particularly difficult problem. For example, the difference in 100% defoliation and 100% loss of stand cannot be distinguished on film. The resultant loss of yield can be vastly different for each case. These two damages occur in combination which makes the problem very difficult. Complete control of each crop by stage, in the data processing steps, will be an absolute necessity.

The results of the research pertaining to the second objective, use of aerial photographs to delineate severe hail damage for field operational applications, appear quite useful; as a consequence, the Country Companies formed an Aerial Survey Department which will be obtaining aerial photographs and supplying copies of them to the adjusters for use as a guide in their adjustments, particularly, in major large storms. This resulted from a pilot project conducted in July-August 1975 to determine if adjusters could use the photographs in actual adjusting. The results were positive and a series of meetings were conducted with the Country Companies officials to help arrange and set up the department and to help train adjusters.

The decision to form the Aerial Survey Department was made by Country Companies in January 1976. The operational plan of the Department called for obtaining infrared aerial photographs on selected major storms during the summer of 1976. The aerial photographs (transparencies) would then be rephotographed and 5 x 5 prints supplied to selected adjusters for special training for use in adjusting.

The Aerial Survey Department of the Country Companies is now in full operation. It has already obtained aerial photographs on one major June storm. The formation of this department was a direct result of techniques developed as part of this research project and the close cooperation between the Illinois State Water Survey staff and the Country Companies staff.

Another benefit from the project relates to a computer mapping program developed as part of the first objective. The ability to put the information for a particular field into map form was necessary so that areas of damage, the field average, and final adjustment figures could be determined. The inability to get desired results to satisfy the first objective was unfortunate; however, the quantified mapping program can be used to produce more accurate field maps based on loss assessments obtained by adjusters.

Some initial analyses have been performed using the program to study how different numbers of sample points (per field) and various sampling methods affect the accuracy of the average loss of yield for a field. More research is necessary before an optimum system combining knowledge about field sampling and the mapping program can be produced for use by the Country Companies. The production of a computer mapping system suitable for accurately mapping crop-hail losses within a field, based on loss assessments by an adjuster, is the primary objective of the research project for 1976-1977.

REFERENCES

Barron, N. A., S. A. Changnon, Jr., and J. Hornady, 1970: Investigations of Crop-hail Loss Measurement Techniques. Res. Rept. 42, Crop-Hail Insurance Actuarial Association, Chicago, 65 pp.

Changnon, S. A., Jr., and N. A. Barron, 1971: Quantification of crop-hail losses by aerial photography, J. Appl. Meteor., 10, 86-96.

Fisher, R. A., Editor., 1936: The Use of Multiple Measurements in Taxonimic Problems. Annuals of Eugenics (Human Genetics), Vol. 7, 179-188.

Jackson, J. R., 1970: Corn aphid infestation computer analyzed from aerial color infrared, Photogrammetric Engineering, 40, 943-952.

Philpott, L. E., and V. R. Wallen, 1969: IR color for crop disease identification. Photogrammetric Engineering, 35, 1116-1125.

Towery, N. G., J. R. Eyton, S. A. Changnon, Jr., and C. L. Dailey, 1975: Remote sensing of crop-hail damage. Report of Research, May 15, 1974 to May 14, 1975 for the Country Companies, 29 pp.

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APPENDIX A

COMPUTER MAPPING INSTRUCTIONS AND COMPUTER MAPPING PROGRAM

PROGRAM HAIL MAP (HMAP) INSTRUCTIONS

CARD 1: MAP CARD

COLS 1-2 NMAPS NUMBER OF MAPS TO BE RUN (R.J.)

CARD 2: TITLE CARD

COLS 1-80 ID ANY DESIRED TITLE

CARD 3: VARIABLE FORMAT CARD

COLS 1-80 VARIABLE FORMAT TO READ IN X Y Z DATA WHERE
X=X-COORDINATE OF FIELD INVESTIGATORS SAMPLE POINT
Y=Y-COORDINATE OF FIELD INVESTIGATORS SAMPLE POINT
Z=% DAMAGE AT THAT POINT

COL 1 MUST BE A LEFT PARENS FOLLOWED BY THE FLOATING POINT FORMAT OF THE DATA CARDS AND THEN FOLLOWED BY A RIGHT PARENS.
EXAMPLE:
COL 1: (3F10.2)

CARD 4: FIELD INFORMATION CARD

COLS 1-4	FI	FIELD NAME
5-9	PHI-2	PHOTO NUMBER
11-14	IA	ALTIMETER
16-17	FT	FILM TYPE
19-23	SA	SCALE 1 INCH =______FEET
25-28	CR	CROP
30-33	SC	CROP STAGE
35-36	NP	NUMBER OF OBSERVATIONS (R.J.)
40-49	XMIN	XMIN OF FIELD ON PHOTO
50-59	XMAX	XMAX OF FIELD ON PHOTO
60-69	YMIN	YMIN OF FIELD ON PHOTO
70-79	YMAX	YMAX OF FIELD ON PHOTO

CARD 5: POINT CARD

COLS 1-50	NUM	ALTHOUGH ALL DATA CARDS (SAMPLE POINTS OF FIELD INVESTIGATOR) ARE READ IN A FEWER NUMBER OF POINTS MAY BE SELECTED TO MAKE THE MAP. BY PUNCHING A 1 IN THE COLUMN HAVING THE CORRESPONDING POINT NUMBER THAT POINT WILL BE USED BY THE MAPPING PROGRAM. EXAMPLE: FOR A FIELD WITH 32 POINTS IF THE POINT CARD HAD 1's PUNCHED IN COLUMNS 1, 3, 16, 24, 32 ONLY, THOSE 5 POINTS WOULD BE USED TO MAKE THE MAP. IF ALL 32 POINTS WERE DESIRED, A 1 WOULD BE PUNCHED IN COLUMNS 1-32.
51-60	XSIZE	THE WIDTH OF THE MAP IN INCHES. MAXIMUM WIDTH IS 13.0 INCHES. THE LENGTH OF THE MAP IS AUTOMATICALLY SCALED (F10.2 FORMAT).
61-70	ADJ	THE INSURED VALUE OF EACH ACRE (F10.2 FORMAT).

CARDS 6+: DATA CARDS
CONTAIN X, Y, Z INFORMATION
ACCORDING TO FORMAT IN CARD 3.
ONE POINT PER CARD.

JCL FOR CARD DECK — IBM 360/75

```
/*ID PS=__________, NAME=________
/*ID CODE=_____
/*ID TIME=(1,0), LINES=2000
/*ID OVFL=YES, EJECT=YES, LINECT=68
// EXEC FORTLDGO

           [PROGRAM DECK]

/*
//GO.SYSIN DD *

           [DATA CARDS (CARDS 1-6+)]

/*
```

```
               DIMENSION XX(50),YY(50),ZZ(50)
               DIMENSION NUM(50),NV(50)
               DIMENSION X(50),Y(50),Z(50),CCM(50)
               DIMENSION ID(20),FORM1(20)
               DIMENSION XMPC(10)
               REAL*8 CCM
                 READ(5,10) NMAPS
            10   FORMAT(I2)
                 DO 1000 NM=1,NMAPS
               READ(5,11) (ID(J),J=1,20)
               READ(5,11) (FORM1(J),J=1,20)
            11 FORMAT(20A4)
               READ(5,21) FI,PH1,PH2,IA,FT,SA,CR,SC,NP,XMIN,XMAX,YMIN,YMAX,NC
            21 FORMAT(A4,A4,A1,1X,I4,1X,A2,1X,F5.1,1X,A4,1X,A4,1X,I2,3X,4F10.2,I1
              *)
               READ(5,26) (NUM(J),J=1,50),XSIZE,ADJ
            26 FORMAT(50I1,2F10.2)
               DO 30 J=1,NP
            30 READ(5,FORM1) XX(J),YY(J),ZZ(J)
            40 WRITE(6,41) (ID(J),J=1,20)
            41 FORMAT('1',20A4,///)
               WRITE(6,51) FI,PH1,PH2,IA,FT,SA,CR,SC,NP,XMIN,XMAX,YMIN,YMAX
            51 FORMAT(1X,'FIELD: ',A4/1X,'PHOTO: ',A4,A1/1X,'ALTIMETER: ',I4/1X,'
              *FILM TYPE: ',A2/1X,'SCALE: 1"= ',F5.1/1X,'CROP: ',A4/1X,'CROP STAG
              *E: ',A4/1X,'NO OBS: ',I2/1X,'XMIN: ',F10.2/1X,'XMAX: ',F10.2/1X,'
              *YMIN: ',F10.2/1X,'YMAX: ',F10.2/////1X,' X-COORDINATE     Y-COORDI
              *NATE        Z-VALUE',/)
               IF(NC.EQ.0) GO TO 59
               IF(NC.EQ.1) NC=10
               READ(5,52) (XMPC(J),J=1,NC)
            52 FORMAT(10F8.2)
               DO 54 J=1,NP
               N=Z(J)
            54 Z(J)=XMPC(N)
            59 K=0
               DO 110 J=1,50
               IF(NUM(J).EQ.1) GO TO 100
               GO TO 110
           100 K=K+1
               NV(K)=J
           110 CONTINUE
               NOBS=K
               DO 120 J=1,NOBS
               X(J)=XX(NV(J))
               Y(J)=YY(NV(J))
           120 Z(J)=ZZ(NV(J))
               DO 60 J=1,NOBS
            60 WRITE(6,61) X(J),Y(J),Z(J)
            61 FORMAT(3X,F8.2,9X,F8.2,6X,F8.2)
               CALL MOESLV(X,Y,Z,CCM,NOBS)
               CALL MAP(CCM,ID,X,Y,XMIN,XMAX,YMIN,YMAX,NOBS,SA,ADJ,NV,XSIZE)
          1000 CONTINUE
               STOP
               END
```

```
      SUBROUTINE MAP(CCI,ID,X,Y,XMIN,XMAX,YMIN,YMAX,NP,SA,ADJ,NV, XSIZE)
      DIMENSION NC1(10),NC2(10),PT(10),AA(10)
      DIMENSION X(50),Y(50),CCI(50),ID(20),NCOUNT(10),MAP1(130),MAP2(130
     *),MAP3(130),ISX1(10),ISX2(10),ISX3(10)
      DIMENSION NV(50),NX(50),NY(50)
      DIMENSION NSF(10)
      REAL*8 CCI
      DATA MINUS/'-'/
      DATA IBD/'I'/
      DATA NSF/'1','2','3','4','5','6','7','8','9','0'/
      DATA ISX1/' ','-','=','|','|','|','O',' ','O','O'/
      DATA ISX2/' ',' ',' ',' ','-','+','-','X','X','='/
      DATA ISX3/' ',' ',' ',' ',' ','=',' ',' ',' ','+'/
      NCOLS=XSIZE*10.
      XDIF=XMAX-XMIN
      YDIF=YMAX-YMIN
      XNY=(YDIF/XDIF*NCOLS)*.8+.5
      YI=YDIF/(XNY-1.)
      XI=XDIF/(NCOLS-1)
      NYY=XNY
      DIF=(130-NCOLS)/2.
      NDIF=DIF
      DO 10 J=1,NP
      NX(J)=(X(J)-XMIN)/XI+1.5
   10 NY(J)=(Y(J)-YMIN)/YI+1.5
      DO 25 J=1,10
   25 NCOUNT(J)=0
      WRITE(6,31) (ID(J),J=1,20)
   31 FORMAT('1',20A4,///)
        DO 300 J=1,130
  300 MAP1(J)=ISX1(1)
      DO 310 J=1,NCOLS
      K=J+NDIF
  310 MAP1(K)=MINUS
      WRITE(6,58) (MAP1(K),K=1,130)
        SUM=0.0
      DO 55 K=1,NYY
      DO 42 J=1,130
      MAP1(J)=ISX1(1)
      MAP2(J)=ISX1(1)
   42 MAP3(J)=ISX1(1)
      YB=YMIN+(K-1)*YI
      DO 50 J=1,NCOLS
      XB=XMIN+(J-1)*XI
      ZC=0.
      DO 370 L=1,NP
  370 ZC=ZC+CCI(L)*SQRT((X(L)-XB)**2+(Y(L)-YB)**2)
        IF(ZC.GT.100.) ZC=100.
        IF(ZC.LT.0.) ZC=0.
        SUM=SUM+ZC
      NSPP=ZC/5.+1
      IF(NSPP.LT.1) NSPP=1
      IF(NSPP.GT.20) NSPP=20
      NSP=ZC/10.+1
      IF(NSP.LT.1) NSP=1
      IF(NSP.GT.10) NSP=10
      NCOUNT(NSP)=NCOUNT(NSP)+1
      I=J+NDIF
      MAP1(I)=ISX1(NSP)
```

```
              MAP2(I)=ISX2(NSP)
           50 MAP3(I)=ISX3(NSP)
              NZZ=NCOLS+1+NDIF
              MAP1(NZZ)=IBD
              MAP1(NDIF)=IBD
              DO 51 L=1,NP
              IF(NY(L).EQ.K) GO TO 52
              GO TO 51
           52 IF(NV(L).LT.10) GO TO 53
              NF=NV(L)/10
              NS=NV(L)-NF*10
              IF(NS.EQ.0) NS=10
              GO TO 54
           53 NF=NV(L)
           54 KL=NX(L)+NDIF
              IF(NX(L).EQ.NCOLS.AND.NV(L).GT.10) KL=NCOLS-1
              MAP1(KL)=NSF(NF)
              MAP2(KL)=ISX1(1)
              MAP3(KL)=ISX1(1)
              IF(NV(L).LT.10) GO TO 51
              KL=KL+1
              MAP1(KL)=NSF(NS)
              MAP2(KL)=ISX1(1)
              MAP3(KL)=ISX1(1)
           51 CONTINUE
              WRITE(6,58) (MAP1(J),J=1,130)
              WRITE(6,59) (MAP2(J),J=1,130)
           55 WRITE(6,59) (MAP3(J),J=1,130)
           58 FORMAT(1X,130A1)
           59 FORMAT('+',130A1)
              DO 200 J=1,130
          200 MAP1(J)=ISX1(1)
              DO 210 J=1,NCOLS
              K=J+NDIF
          210 MAP1(K)=MINUS
              WRITE(6,58) (MAP1(K),K=1,130)
              TOTFRE=0.
              DO 150 J=1,10
          150 TOTFRE=TOTFRE+NCOUNT(J)
              TOTAR=(XDIF*YDIF*SA**2)/43560.
              DO 151 J=1,10
              NC1(J)=(J-1)*10
              NC2(J)=NC1(J)+10
              PT(J)=NCOUNT(J)/TOTFRE*100.
              AA(J)=PT(J)/100.*TOTAR
          151 XNC1=NC1(J)
              WRITE(6,66)
           66 FORMAT(1X,///,40X,'SYMBOL',8X,'CLASS',7X,'FREQUENCY',9X,'AREA',/51
             *X,'(% DAMAGE)',8X,'(%)',11X,'(ACRES)',/)
              DO 100 J=1,10
              DO 70 II=1,3
              WRITE(6,60) ISX1(J),ISX1(J),ISX1(J)
              IF(II.EQ.2) GO TO 71
              WRITE(6,61) ISX2(J),ISX2(J),ISX2(J)
              GO TO 72
           71 WRITE(6,62) ISX2(J),ISX2(J),ISX2(J),NC1(J),NC2(J),PT(J),AA(J)
           72 WRITE(6,61) ISX3(J),ISX3(J),ISX3(J)
           70 CONTINUE
              WRITE(6,77)
```

```
0117           77 FORMAT(1X,/)
0118          100 CONTINUE
0119                 WA=(SUM/(NYY*NCOLS))
0120                 TADJ=ADJ*TOTAR*WA/100.
0121                 WRITE(6,63) TOTAR
0122           63 FORMAT('0',82X,F6.2,' = TOTAL ACREAGE')
0123              WRITE(6,111) WA
0124          111 FORMAT(1X,///41X,'AVERAGE OF % DAMAGE FOR ENTIRE FIELD BASED ON AL
                 *L EVALUATED MAP POINTS= ',F6.2,' %')
0125           64 FORMAT(1X,///41X,'INSURED VALUE OF EACH ACRE= $',F6.2,//41X,'TOTAL
                 * ADJUSTMENT= $',F8.2)
0126              WRITE(6,64) ADJ,TADJ
0127           60 FORMAT(41X,3A1)
0128           61 FORMAT('+',40X,3A1)
0129           62 FORMAT('+',40X,3A1,9X,I2,'-',I3,8X,F6.2,8X,F8.2)
0130              RETURN
0131              END
```

```
      SUBROUTINE MQESLV(X,Y,Z,CCI,NR)
      DIMENSION X(50),Y(50),Z(50),AA(50,50),CCI(50),ZA(50)
      INTEGER*4 IDUM(50)
      REAL*8 AA,DSQRT,XX1,YY1,XX2,YY2,CCI,ZA
      DO 10 I=1,NR
      XX2=X(I)
      YY2=Y(I)
      DO 10 J=1,NR
      XX1=X(J)
      YY1=Y(J)
   10 AA(I,J)=DSQRT((XX1-XX2)**2+(YY1-YY2)**2)
      DO 20 I=1,NR
   20 ZA(I)=Z(I)
      IER=1
      CALL GAUSZ(AA,NR,50,ZA,CCI,IDUM,IER)
      RETURN
      END
```