01

253045

E7.4-10.7 0 3
CR-139323

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle REMOTE SENSING IN IOWA AGRICULTURE Identification & classification of Iowa's crops soils and forestry resources using ERTS-1 and complimentary underflight imagery.		5. Report Date May 28, 1974
		6. Performing Organization Code MMC #249
7. Author(s) J.P. Mahlstede, A. Epstein R.E. Carlson, T.E. Fenton, G.W. Thomson		8. Performing Organization Report No. Nine
9. Performing Organization Name and Address Iowa State University Agriculture Experiment Station Ames, Iowa 50010		10. Work Unit No.
		11. Contract or Grant No. NAS5-21839
		13. Type of Report and Period Covered Type III Report 18 mo end May 1974
12. Sponsoring Agency Name and Address Goddard Space Flight Center Greenbelt, Maryland 20771 Stonesifer, G. Richard, X 2856, Code 430		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract This research has been directed towards inventory of cropland and forestland and towards soil association mapping using ERTS-1 imagery. The following summarizes this work. 1)Cropland identification and acreage estimates - only limited acreage estimates have been attempted to date as digital analysis using CCT's appears most practical and is just beginning. We report a temporal digital classifier for central Iowa. Cropland identification of temporal ERTS-1 data visually appears to separate most crop types, but the timing of satellite coverage is critical. Broad synoptic cropland usage is discussed. 2) Forested land estimates - acreage estimates of forestland in 8 townships in central Iowa were attained using wintertime ERTS-1 imagery. Comparisons with known ground truth are presented and indicate these estimates may be attainable using CCT's. 3) Soil association mapping-ERTS-1 imagery comprised of springtime MSS7 were used to produce a state mosaic. Vegetation differences are noted and relate to topography and soils. Major soil associations are apparent, illustrated and discussed. Clouds and haze were present in some areas. 4) Crop disease detection - Crop diseases were evident on the underflight imagery at test sites; however, detection from satellite imagery was hampered by resolution, normal crop senescence and other field anamolies.

17. Key Words (Selected by Author(s)) crop and forestland inventory, soils mapping, ERTS-1 imagery, temporal analysis, disease detection		18. Distribution Statement Original photography may be purchased from: EROS Data Center 10th and Dakota Avenue Sioux Falls, SD 57198	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 71	22. Price*

ORIGINAL CONTAINS COLOR ILLUSTRATIONS

TABLE OF CONTENTS

PREFACE

a) Objectives

The objectives of this investigation are as follows:

1. To evaluate how remote sensing data can be utilized in Iowa to better or more economically define the soil and plant parameters that are important in production and marketing of agricultural crops.
2. To evaluate the ERTS-1 satellite for conducting forestland, cropland and soil classification surveys by noting the constraints of the system, by identifying problem areas and by suggesting solutions to these problems where possible.
3. To determine how these data can be utilized in decision-making processes involving optimum utilization of our natural resources.

b) Scope of work

The effort at Iowa State University includes researchers in plant pathology, agricultural climatology, soil classification and morphology, forestry and photography and their associated problems related to remote sensing using both satellite and underflight imagery of various formats. Standard photo-interpretive methods have been used to date in the analysis of this imagery. Digital analysis of the satellite data is just in the initial stage.

c) Conclusions

The usefulness of ERTS-1 imagery for achieving cropland, forestland or soil association mapping estimates depend upon two critical factors. First, atmospheric impurities, haze or clouds, seriously reduce the image quality. This was noted when comparing August 72 and 73 imagery. Second, timing of satellite coverage determines the major features which can be observed. For instance, wintertime (MSS7) imagery which is accentuated with snow cover highlights forested land. Springtime (MSS7) imagery reveals major land use patterns resulting from the adaptability of vegetation to soils present and associated topography. Summertime, particularly August, imagery aids in the separation of major crop types grown in Iowa. The multi-spectral utility of ERTS-1 is noted here as MSS band 5 separates towns, roads and stubble, whereas MSS7 aids in the separation of corn and soybean fields. It must be emphasized that when attempting cropland estimates, agriculture is a dynamic enterprise and timing of satellite coverage can be extremely critical with respect to the crop response noted.

In addition to the multi-spectral separations achievable on ERTS-1 imagery, the temporal aspect can be a powerful tool in vegetation analysis. This aspect will be further researched by investigators involved with this project. Only limited area estimates have been attempted to date using ERTS-1 visual products as we are just beginning to analyze the data provided on the digital tapes. We feel these estimates will be more meaningful using the CCT's than using visual estimates. Resolution may continue to be a problem with respect to the imagery type, however, final recommendations can not be stated until the analysis of the digital tapes is completed and compared to actual ground truth. ERTS-1 imagery lacks the very detailed information available from low level platforms, however, ERTS-1 provides the broad synoptic aspect of a given area and this adds another dimension to photo-interpretation.

d) Summary of recommendations

Analysis of ERTS-1 imagery received to date, indicates that timing of satellite coverage is a critical factor determining what is perceivable on the imagery. Depending on image quality, date of coverage and the immediate surroundings, quite small fields were easily seen. In some cases, the 18 day cycle puts a restraint on the imagery available for analysis. For example, 1 test site in Iowa was seen by ERTS-1 only 2 times during the 1973 crop growing season. However, temporal coverage is a powerful tool for the photo-interpreter involved with vegetation analysis. Area estimates of soils, crops and forested land have not been attempted to a large extent to date because we feel this will be more adapted to digital analysis of CCT's. Initial results are encouraging. Maximum information will probably be attained using a mixture of visual and digital products.

List of Figures

List of Tables

BODY OF REPORT

Introduction

Iowa is a strong agricultural state with its population dependent on the varied types of production from border to border. The soils, crops, forests and water sources comprise the natural resources needed for the production of these agricultural products. Because of this, concern must be directed toward their efficient use. One aspect of their efficient use is an inventory or accounting of their extent in both time and space. Remote sensing has been shown to be a valuable tool in this respect; therefore, this continuing investigation has been directed toward the use of various remote sensing techniques and products, in this regard at three test sites. Low level and space platforms have viewed Iowa during 1972, 1973 and 1974 acquiring various photographic and digital products. This report examines the capabilities, assessed to date, of ERTS-1 to obtain these desired surface parameters. Emphasis will be placed on cropland, forestland and soil resources.

Methods of Analysis

Three areas with differing soils and cropping patterns in Iowa were selected for experimentation. In addition, other areas have been examined as new ERTS-1 imagery was available. The acquired imagery has been subjected to standard photo-interpretative techniques as the digital analysis of the ERTS-1 CCT's is only beginning. The interpretative techniques utilized to date are as follows: 1) direct enlargement of the 70 mm positive transparencies, 2) additive color procedures using the I^2S miniadcol system located at and with the permission of the Iowa State Geologic Survey - Remote Sensing Center at Iowa City, Iowa and 3) direct examination of the 70 mm positive transparencies using a low power microscope with an x-y vernier stage.

Ground truth data have been acquired at these test sites for later correlation with the conditions indicated on the ERTS-1 imagery. A part of this ground truth has been obtained through underflights provided by NASA in the early spring and late summer time periods. This particular ground truth has been an indispensible part of this investigation and it has provided a very precise record of ground conditions not otherwise available to this research group. The format of this imagery included color infrared, regular color and black and white multiband transparencies acquired from altitudes ranging from 3,000 to 60,000 feet during both 1972 and 1973.

Results and Discussion

1) General statements concerning ERTS-1 coverage and usefulness during the duration of this project.

The ERTS-1 satellite views the earth from 565 miles. Thus, much of the detail possible via other types of remote platforms is not possible. However, this view from space provides to researchers the broad synoptic features of a region. This is a very important advantage in many disciplines and will be discussed in this report.

The first ERTS-1 imagery acquired by this group corresponded to the late crop growing season and the temporal and multi-spectral aspects of this type of imagery were not fully appreciated until 1973. These points will, also, be discussed. The atmosphere and its state have a strong control over the quality of imagery acquired via the satellite. Clouds obviously are a detriment to the researcher concerned with surface features, but atmospheric haze can cause serious problems with respect to image quality. Both high quality and the other type of imagery have been examined by this group.

The repetitive cover provided by the 18-day cycle is a strong asset and can provide very informative data, if the atmosphere is clear. Our experience during the 1973 crop growing season resulted in both excellent and very poor coverage of the test sites. The overlap present at 42° N latitude was fortunate as two test sites were in this area of satellite coverage. Thus, if clouds were present on one day, then another chance for good imagery was possible on the other day of each cycle. Because of this feature, the test site in northwestern Iowa was successfully viewed at least once each month during the 1973 crop growing season.

2) General statements concerning NASA provided low level photographic products.

The cooperation with the Houston-based personnel was excellent with regard to the acquisition of this necessary ground truth record at the test sites. Timing of low level flights was very close to satellite coverage. The photographic products were of excellent quality and, except for a minor portion of 1972 imagery, were cloud free. Other individuals besides our immediate research group have viewed this imagery with much interest. This imagery has provided a permanent record of surface conditions during time periods critical to vegetation development. It was an indispensible part of this project regarding comparison of features viewed from space.

The diversity of the studies of individual researchers is such that each investigator's results and discussion section will be separately discussed on the following pages of this report.

Results and Discussion: Cropland Inventory by Richard E. Carlson, Assistant Professor of Agricultural Climatology, Iowa State University.

1) Crop identification and inventory at the predetermined test sites - 1972

Field visits to considerable portions representative of each test site in conjunction with visual examination of the NASA provided underflight imagery were employed to obtain accurate ground truth providing both field identification and acreage estimates in both 1972 and 1973. Examples of the underflight imagery are presented in Figures 1-5.

a) Ames, Iowa flightline

Acreage estimates determined from the underflight imagery for corn and soybeans in twelve sections of the Ames flightline were 2651 and 2046, respectively. These estimates were assumed correct and similar estimates were obtained utilizing the August ERTS-1 imagery. Previous point sampling for crop identification yielded Fig. 6, showing that corn and soybeans could be separated using MSS bands 5 and 7. But, a more detailed study (Table 1) revealed that misclassifications were present.

Table 1. Error analysis of field type classification for 118 randomly placed points in the twelve section Ames flightline using August - 1972 ERTS-1 MSS5 and MSS7 black and white enlargements.

		Ground Truth			Total seen by P.I.	Commission Error	Percent
		Soybeans	Corn	Other			
PI's results from ERTS-1	Soybeans	48	6	0	54	6	11.1
	Corn	12	39	1	52	13	25.0
	Other	0	2	10	12	2	16.7
Total Plots		60	47	11			
Omissions		12	8	1			
Percent Correct		80.0	83.1	90.8			

With these results in mind, more meaningful acreage estimates were attempted for this area using a crude project-trace-cut and weigh procedure as image quantification methods were not available. These methods are described in Appendix A. Black and white single band prints (MSS bands 5 and 7), mini-adcol produced color slides or photo-micrographs of 70 mm bulk positive transparencies were used. The paper weight was converted to acreage using an adjacent calibration strip. These results are given in Table 2.

Table 2. Estimation of soybean acreages in twelve sections in the Ames flightline by 3 project-trace-and-weigh methods and 1 dot placement method.

Method	ERTS-1 estimate	Actual	Difference	Actual/ERTS-1 estimate
Miniadcol	2065	2046	19	.991
Photomicrograph	1813	2046	233	1.128
Photo-cut	1903 (2333)[1]	2046 (2651)	143 (318)	1.075 (1.136)
Dot placement	1804	2046	242	1.134

[1] corn acreage estimates in parenthesis

Although not bad estimates, errors in placing field boundaries and difficulty in identifying field types as projected on the flat surface required that additional study was needed. Analysis of commission and omission errors was completed for three sections. These results are given in Table 3 and verified that fields were misclassified or field boundaries were misplaced. Image degradation due to multiple processing to a usable product and small field size probably were causing problems. The average size of soybean fields in this area was 24.6 acres and corn field size would probably be comparable.

Table 3. Error analysis of crop type acreage estimates of projected miniadcol produced color slides for three sections in the Ames flightline (August - 72)

		ERTS-1 estimates					
		corn	soybeans	other	total	omission	%
Ground Truth	corn	633	74	60	767	134	17.5
	soybeans	62	365	51	478	113	23.6
	other	180	127	358	665	307	46.2
	total	875	566	469			
	commission	242	201	111			
	%	72.3	64.5	76.3			

b) Doon, Iowa flightline

Similar ERTS-1 acreage estimates were made in the Doon flightline; however, this proved to be a very difficult task in this part of Iowa using August imagery. The flightline covers an area including a small river drainage system. This influenced the response on MSS6 and MSS7 (used to separate corn from soybeans) such that field patterns were completely diffused. MSS5 was quite sharp and detailed in this area, but corn and bean fields are not separable using this wavelength alone at this time. Another feature of this area which makes soybean classification difficult is the fact that very few soybeans were present. The ground truth acreage for corn and soybeans in the 12 section flightline was 3517 and 702, respectively.

Before any area estimates of field types were attempted in the Doon flightline, point-sample identification estimates were made using miniadcol produced color slides. The miniadcol slides were projected to an enlargement the same size as projected underflight imagery (black and white 5-inch film exposed with a #89B filter). Points were planted according to underflight fields by one individual, then another individual classified each point on the miniadcol slide based on previously established color signatures. These results are given in Table 4.

Table 4. Error analysis of field type classification for 47 placed points in six sections of the Doon flightline using August 1972 ERTS-1 imagery of the miniadcol produced slide format.

		Ground Truth			Total seen by	Commission	
		Corn	Soybeans	Other	P.I.	Error	Percent
PI's results from ERTS-1	Corn	16	0	1	17	1	5.9
	Soybeans	2	10	4	16	6	37.5
	Other	5	0	9	14	5	35.7
Total plots		23	10	14			
Omissions		7	0	5			
Percent		69.6	100	64.3			

Of the twelve fields misclassified in this analysis, seven fields exhibited abnormal responses on the low level color infrared underflight imagery.

After this point analysis, acreage estimates were attempted for five other sections in the Doon flightline using the ERTS-1 miniadcol produced color slides. Error analysis for these sections is presented in Table 5 using the project-trace-and-weigh procedure from miniadcol produced color slides. This table indicates that considerable acreages of corn and

Table 5. Error analysis for five sections in the Doon flightline using miniadcol produced slides (August 1972).

		ERTS-1 estimates					
		corn	soybeans	other	total	omission	%
Ground Truth	corn	566	23	496	1085	519	47.8
	soybeans	28	133	181	342	209	61.1
	other	148	60	1750	1958	208	10.6
	total	742	216	2427			
	commission	176	83	677			
	%	76.3	61.6	72.1			

soybeans were misclassified as before using the miniadcol produced slides. Overlaying ground truth on the ERTS-1 classification showed that major acreage errors can be directly attributed to the failure of the photo-interpreter to outline large enough areas for certain fields. This was a very difficult area to classify because the field boundaries were very diffuse and the individual field colors were not sharp and distinct. Very seldom were fields missed altogether as indicated in Table 4.

East of the Doon flightline, the image quality of MSS5 and MSS7 improved very markedly. This change is related to topographic differences between these areas resulting with more uniform and larger fields being present east of the Doon flightline. This is illustrated in Fig. 7. (Note: the prints in this report are for illustrative purposes, larger prints were used for acreage estimates). Acreage estimates of corn and soybeans were attempted using the procedures described in Appendix A. These results follow.

c) O'Brien County, Iowa flightline

Actual ground truth was not available for this county. Estimated ground truth was requested and provided by the Iowa Crop Reporting Service for townships in O'Brien County, Iowa where 1972 corn and soybean acreage estimates existed. The results of the ERTS-1 acreage estimates are summarized in Table 6.

Table 6. Acreage estimates of soybeans for eight townships in O'Brien County, Iowa using four different methods.

	% of total land by townships					Differences			
Township	CRS	Mini	Opaque	Micro	Photocut	CRS-Mini	CRS-Opaque	CRS-Micro	CRS-Photocut
Franklin	19.9	20.8	21.4	23.4	27.6	-00.8	-01.4	-03.4	-07.6
Lincoln	26.0	25.3	29.2	26.0[1]	27.4[1]	00.7	-03.2	00.0	-01.4
Summit	32.9	20.1	31.2	--	--	12.8	01.7	--	--
Center	30.4	19.1	24.5	32.6[2]	30.0	11.3	05.9	02.2	00.4
Omega	23.5	16.4	21.8	--	--	07.1	01.7	--	--
Grant	23.9	14.9	23.2	24.8	--	09.0	00.7	00.9	--
Liberty	23.1	16.0	23.3	28.0	--	07.1	00.2	04.9	--
Waterman	10.4	15.2	10.7	--	--	04.8	00.3	--	--
					$\bar{X}_{dif}$	06.7	01.9	02.3	03.1

[1] average of 2 acreage estimates
[2] average of 3 acreage estimates

It must be emphasized that the ground truth obtained from the Crop Reporting Service is an estimate based on sampling and not an estimate based on photo-interpretation of the area in question. For this reason, the Crop Reporting Service estimate may differ slightly from the true acreage present. The author feels that the comparisons in Table 6 are valid under these circumstances.

As in Table 5, Table 6 shows that the miniadcol produced color slides tend to underestimate soybean acreages, at least using this imagery. Again, this error probably arises from the fact that individual field sizes are underestimated. The most consistent and accurate method used in this analysis was the projection of enlarged prints using an opaque projector. The projected image was traced using previously established soybean signatures and, subsequently, weighed and converted to acres. With the exception of the photomicrograph projection technique for the first soybean acreage estimate in Center township, the remaining estimates are probably within the standard errors associated with these techniques.

These errors are related to the photo-interpreters ability to discern shades of black and white or differences in color on the projected image, his ability to consistently place field boundaries in the same place due to the diffuseness of the ERTS-1 enlargement, the possibility that the calibration strip may be in error, and the errors associated with the cut-outs, cutting and weighing. In addition, these methods assume that all soybean fields in areas of interest yield distinct spectral responses. This is, in fact, not true as evidenced by the fact that earlier point sampling in the Doon area showed that some misclassified soybean fields were abnormal looking fields on the low level color infrared imagery. It should be noted that in Table 6 where footnotes indicate that multiple acreage estimates were made for a given township using a specific method, these estimates were not completely consistent. An insufficient number of samples were obtained to develop reliable statistics; however, the variability was due mainly to the photo-interpreters ability to discern shades of black to white and accurately place field boundaries in the same position each time.

d) Closing remarks concerning the analysis of the 1972 ERTS-1 imagery.

In 1972 ERTS-1 coverage of Iowa test sites was limited to one time during the later portion of the growing season. Visual analysis of black and white and miniadcol produced color products indicated that cropland acreage estimates were not adequate. This occurred because visual spectral field response differences could not be completely separable between all crop types of interest using MSS5 and MSS7. (MSS6 appeared very similar to MSS7 and MSS4 generally lacked contrast and detail.) For example, some pasture land was confused with corn fields and uncut alfalfa fields were sometimes misclassified as soybean fields. In addition, acreage estimates using visual techniques were attainable in the test site areas, but these estimates were very tedious and time consuming. Also, shades of grey visual differences between field types were sometimes difficult for the photo-interpreter. For these reasons, the emphasis during the 1973 crop growing season has been directed toward achieving crop field response differences based on both multi-spectral and temporal aspects of ERTS-1 imagery. Acreage estimates have not been attempted using visual procedures because this research group is presently beginning to utilize ERTS-1 CCT's. This researcher feels that acreage estimates will be more meaningful and can be obtained less tediously using digital procedures if adequate spectral field response differences can be attained.

2) Crop identification and inventory at the predetermined test sites - 1973

a) Temporal and multi-spectral features of ERTS-1 imagery regarding vegetation development in Iowa.

Satellite coverage over Iowa during the 1973 crop growing season varied considerably between test sites. Western Iowa was viewed at least once each month from May through October. Central Iowa coverage was not as complete, but adequate with respect to crop development. The eastern Iowa test site at Independence experienced very poor coverage due to cloud cover, one time in June and later coverage in September and October.

Figures 7 through 10 illustrate the usefulness of combining multispectral analysis temporally to accentuate vegetation types and possible changes in vegetation. This will be discussed further in the sections which follow pertaining to each test site. Figure 10 clearly separated vegetation from intensively cultivated areas so using the standard catalogs provided by NASA, springtime ERTS-1 imagery covering Iowa was requested, received and assembled resulting in Fig. 11. This figure essentially shows areas of actively growing vegetation (trees, pasture and hay) - dark, bodies of water - white, and fields (corn, soybeans, oats, etc.) which were in various states of springtime tillage - light and grey. Areas of Iowa which are intensively row-cropped are apparent (lighter areas). These features result from the land use adapted to an area, depending upon the soils present and topography. (Note: the close correspondence between Figs. 11 and 12.) Soil patterns noted in these two figures are discussed in detail in a later part of this report.

b) <u>Independence, Iowa flightline</u>

Due to the cloud cover present at this site during the 1973 orbital coverage, very little work has been completed at this test site. The June 1973 imagery does illustrate, however, one aspect of the broad synoptic features noted on ERTS-1 imagery. Figure 13 is a miniadcol produced color infrared rendition of a portion of that imagery. Red fields at this time were either pasture, forestry or alfalfa. Fields which were planted to corn, oats or soybeans had not yet attained the red response as the canopy did not cover the soil surface. The change in field color noted while traversing from left to right reflects the agricultural land use with respect to corn and soybean production. This is related to the soils and topography present in this area and the adaptability of the land for intense row-crop production. Another point to be noted from this print is the lighter area in the center. One could suggest that response to be soil related. However, this response could be attributed to atmospheric haze. Good multi-date coverage would be necessary to determine its cause.

c) Doon, Iowa flightline

ERTS-1 coverage of northwestern Iowa was extremely good because of the absence of cloud cover and atmospheric haze. In fact, the Doon flightline was observed by ERTS-1 once each month during the crop growing season. The probability of this was aided because this flightline occurs in the ERTS-1 daily overlap area. Clear conditions generally existed on one of the two days possible each eighteen day cycle. In addition, when clouds were present, they were not over the test site. To date the analysis of imagery in this area has been restricted to black and white or miniadcol produced color products. The intent is to achieve a crop response classifier for this area using temporal, multispectral data.

The visual black to white response of known fields in this flightline is summarized in the following table. (Note that MSS7 was used primarily until the August time frame as it was the superior and most detailed imagery when compared to the other MSS bands recorded before August.)

Black and white visual analysis of MSS7 revealed that fields to be planted to corn and soybeans were separable from alfalfa and pasture using May 11th, May 30th or June 16th imagery (Table 7). The separation between oats fields and corn or soybean fields was less distinct.

Table 7. Mean values of the quantified[1] visual black to white field responses as perceived on black and white enlargements of the Doon flightline.

Crop Type[2]	Date and MSS Band					
	5/11 MSS7	5/30 MSS7	6/16 MSS7	7/4 MSS7	8/10 MSS7	8/10 MSS5
Pasture	1.0	1.2	1.6	2.0	3.0	2.0
Soybeans	2.5	2.9	2.9	2.0	1.0	3.0
Corn	2.9	2.9	2.9	2.0	3.0	3.0
Oats	1.6	1.7	1.8	1.6	3.0	1.6
Alfalfa	1.1	1.1	1.7	1.0	1.7	3.0

[1] 1 to 4 correspond to dark to light visual responses, respectively.

[2] Number of like fields may vary between dates because of cloud cover.

On June 16th imagery some alfalfa fields did not appear nearly as dark, indicating first crop harvest. Crop Reporting Service estimates indicate that in this region over the previous three years, 70% of the first crop had been harvested on June 20th. This spectral response anamoly was also noted on miniadcol color products. (Note: Table 8, compare May 30 and June 16 alfalfa responses.) July 4th imagery was not as sharp or detailed as May or June imagery, however, most dark fields in the Doon flightline were alfalfa fields.

August 10th imagery probably provides the most information at this stage of the crop response classifier. Corn and soybean fields appear very different with respect to shades of grey. However, at this time, some alfalfa fields yield a response similar to soybeans. These fields would have to be accounted for on earlier imagery. This appears likely. Corn, oats and pasture give similar responses, however, the use of MSS5 at this date provides the necessary separation of corn fields from pasture and oats fields. Separation of oats and pasture may require more refined methods of separation than visual methods employed here.

Thus, by proper selection of MSS bands and dates of coverage, most field types are separable with respect to visual responses as perceived on the ERTS-1 enlargements. Resolution may remain a problem with respect to acreage estimation due to the orbital restraints. In addition, final evaluation would require analysis of the digital data to verify these visual separations.

Color products were produced on the miniadcol system available to this group using both standard color/filter combinations and, also, false color/filter combinations using pre-selected MSS bands from different ERTS-1 cycles. The previously described visual black and white analyses were restricted to single-date and single-band analysis. Examples of the color products covering this area are shown in Figures 14 through 18 including an example of Skylab imagery. The intent was to determine if various fields of interest could be separated because of the temporal variation in the multi-spectral response of these fields. If they were separable via additive color procedures, then digital tape analysis should yield similar separations automatically. For example, plowed ground intended for corn or soybean planting is visually separable from other field types on springtime MSS7. Proper selection of other MSS bands and dates can lead to color separations of corn and soybeans from other field types as is illustrated in Fig. 19. The visual color responses are summarized in Tables 8 and 9 for Figures 14 through 16. Similar false color imagery have been produced at the Ames test site and will be discussed in that section.

Table 8. Color response of five crop types in the Doon flightline as viewed on projected Miniadcol produced color infrared slides for 3 sequential dates in early 1973.

		Number of fields[1]				
Date	Crop Type	Red	Diffuse Red	Dark	Diffuse White	White
May 11	corn	0	1	46	0	0
	soybeans	1	2	10	1	0
	pasture	8	0	0	0	0
	alfalfa	9	4	0	0	0
	oats	2	9	1	5	4
May 30	corn	0	0	28	21	0
	soybeans	1	0	7	7	0
	pasture	2	6	0	0	0
	alfalfa	11	4	0	0	0
	oats	5	16	0	0	0
June 16	corn	0	5	44	0	0
	soybeans	0	2	9	1	0
	pasture	5	3	0	0	0
	alfalfa	3	7	0	3	2
	oats	13	8	0	1	0

[1] Number of like fields may differ between dates because of cloud cover.

Table 9. Color response of various field types as viewed on a projected slide representing a miniadcol false color rendition using the following color filters and MSS bands: May 11, 1973 - MSS5 (blue) and MSS7 (red); June 16, 1973 - MSS5 (blue) and MSS7 (red).

	Color[1]			
Field Type	Brown	Orange	Yellow	Yellow/Orange
Corn	44	3	0	0
Soybeans	10	2	1	0
Pasture	0	0	1	7
Alfalfa	0	3	10	1
Oats	0	18	1	0

[1] General color categories as perceived by photo-interpretor.

d) O'Brien County, Iowa flightline

August of 1972 ERTS-1 imagery covering the area immediately east of the Doon flightline appeared very sharp and detailed. For this reason the August 1973 NASA provided underflights included this area. Examples of this imagery are shown in Figs. 1 and 20. Fig. 20 includes crop types and acreages for one section of this flightline. This is an area of Iowa which is intensively row-cropped as the soils are very fertile and the topography is quite gentle. As with the other previously discussed areas at Doon and Ames, we have attempted to visually produce a crop response temporal classifier by examination of enlarged black and white ERTS-1imagery of this area. ERTS-1 coverage was not as complete as in the Doon flightline because of cloud cover, but the black and white imagery for the most productive ERTS-1 imagery is shown in Fig. 21. (Note: compare with Fig. 20.) The results of this visual analysis are given in Table 10.

Table 10. Mean values of the quantified[1] visual black to white field responses as perceived on black and white enlargements of the O'Brien County flightline.

Crop Type[2]	Date and MSS Band		
	5/29 MSS7	8/9 MSS5	8/27 MSS7
Pasture	1.7	1.4	2.0
Soybeans	1.0	1.0	2.9
Corn	1.1	1.0	2.0
Oats	2.0	2.3	1.9
Alfalfa	2.3	1.2	2.3

[1] 1 to 3 corresponds to light to dark visual responses, respectively.

This set of ERTS-1 imagery appears to give adequate black and white differences to achieve a good crop classification depending upon the inherent resolution of the ERTS-1 satellite. As in the Doon area, no complete spectral separation was attainable so these results would have to be verified by analysis of the digital tapes.

Fig. 21a generally separates oats, alfalfa, pasture and towns from land which will be planted to soybeans and corn in the 1973 crop growing season. Fig. 21b generally separates soybeans and uncut alfalfa from corn, pastureland and towns. Fig. 21c provides information essential to separate towns, roads and stubble fields from corn and soybean fields.

Temporal, visual field responses of known fields have not been completely analyzed at this date for this area, but they appear quite encouraging. In fact, it appears that corn and soybean fields start to separate in the July MSS5 imagery. This was also noted in the other areas and is quite important. (See Fig. 23b). In order to be useful, cropland acreage estimates must be completed early in the crop growing season. If this were achievable, then yield estimates may possibly be applied to the acreage estimate by incorporating production and weather data corresponding to the areas of interest.

e) Ames, Iowa flightline - photographic and visual analyses

Successful coverage of this flightline has been less numerous than the Doon flightline. The times when ERTS-1 passed over have, however, provided this research group with probably our best ERTS-1 imagery to date. As with the other two previously discussed flightlines, visual analysis of temporal, multi-spectral imagery has been emphasized with hopes of developing a crop classifier which would be adaptable to computer analysis procedures using digital data. This analysis is beginning and not nearly complete at this time. Discussion will be presented at the end of this section.

The temporal aspects of the ERTS-1 imagery covering the Ames area have been illustrated in Figures 9 and 10. In addition, winter imagery shown in Fig. 22 greatly accentuates forest cover probably because of a snow covered surface. (Note: As with the springtime state mosaic, the standard catalogs provided by NASA have been consulted and imagery of this type covering the entire state has been ordered and will be assembled into a composite. We have not yet received this imagery.) Springtime imagery shown in Fig. 10 and Fig. 11 reveals the early season vegetation comprised mainly of forest, pasture and alfalfa. Summertime imagery (MSS7) in August helps to separate various crops, mainly corn and soybeans, from crop types which cause misclassification of the 1972 single date analysis. In fact, a partial state mosaic (western half of Iowa) was constructed from this imagery. When examined visually in concert with Fig. 11, the broad synoptic distribution of Iowa croplands is evident. MSS5 in August accentuates towns, major road systems and stubble fields which in central Iowa are mainly oats and alfalfa stubble. As with the other flightlines, black and white responses were visually determined from ERTS-1 enlargements. Examples of the enlargements are given in Fig. 23. A black and white enlargement from the underflight imagery is shown in Fig. 3 for a portion of the imagery shown in Fig. 23. For interested readers, the crop types present in the four sections are given in Table 11.

Table 11. Ground truth for sections 9, 10, 15 and 16 as illustrated in Fig. 3.

Crop Type	Section	Field Number
Corn	9	201, 101 and 204
	10	302, 201, 403, 405 and 505
	15	203, 302, 508, 403, 501, 207, 304, 104, 510 and 504
	16	101, 303, 501, 402, 103, 301, 305 and 505
Soybeans	9	102, 202, 203 and 205
	10	203, 503, 102, 301, 404 and 401
	15	303, 102, 505, 201, 205, 503, 401, 404 and 402
	16	302, 102, 201 and 401
Alfalfa	9	Small plots on the Agronomy Farm
	10	402 and 504
	15	202
	16	None present
Oats	9	Present on the Agronomy Farm, but not designated
	10	101 and 410
	15	206
	16	None present
Pasture	9	Small plots on the Agronomy Farm
	10	202 and 409
	15	101, 301, 509 and 405
	16	None present

The results of this study are summarized in Table 12 and show that separations are possible between crop types, but that response overlaps exist.

Table 12. Mean values and standard deviations of the quantified[1] visual black and white field responses as perceived on black and white enlargements of the Ames flightline.

Crop Type	Date and MSS Band							
	5/10 MSS7		7/2 MSS7		8/26 MSS7		8/26 MSS5	
	x	σ	x	σ	x	σ	x	σ
Pasture	2.6	0.7	2.8	0.4	2.2	0.6	1.5	0.9
Soybeans	1.6	0.5	1.2	0.4	2.9	0.2	1.0	0.2
Corn	1.4	0.5	1.9	0.5	2.0	0.2	1.0	0.2
Oats	2.0	0.0	2.6	0.8	2.1	0.7	2.0	1.0
Alfalfa	2.7	0.5	2.2	0.9	2.4	0.7	1.4	0.7

[1] 1 to 3 corresponds to light to dark visual responses, respectively.

Our intent, however, is to use this preliminary analysis to develop a computer crop response classifier. Then the ERTS-1 digital data corresponding to these dates and spectral bands can be superimposed, classified and compared to actual ground truth. Problems which were noted in the visual analysis are as follows: 1) oats and corn fields were not separable using MSS7 on either May 10th or August 26th. Some oats fields were, however, separable using MSS5 on August 26th. If other MSS5 bands were available shortly after oats harvest, this could be only a slight problem. 2) On May 10th MSS7 imagery, a few dark fields which corresponded to actively growing vegetation were later plowed and planted to soybean fields. This may present a slight problem, but if late May imagery were available, the problem would probably be minimal. 3) Visual appearance of forested and urban areas indicate that their spectral responses will have to be analyzed further before unknown areas are classified using the CCT's and the field response classifier.

In some cases similar spectral responses between forested-urban areas and agricultural areas were noted.

In attempts to further determine visual response differences, the miniadcol system was employed using both single-date normal filter-wavelength combinations and multi-date non-normal filter-wavelength combinations. Initially, we felt very little success could be expected by superimposing imagery of different dates, but registration was not a serious problem. An example of the normal color infrared rendition is given in Fig. 24 with a corresponding print showing the color infrared response obtained from the underflight in Fig. 25. Striking similarities, besides resolution differences, are evident. The visual color-crop type correspondence was as follows: 1) dark - plowed fields which were to be planted to corn or soybeans (the majority of the dark fields were corn as this crop is planted first in the spring), 2) diffuse white - fields with stubble on the surface from the previous growing season's crop (as with (1) above, the majority of these fields were later planted to soybeans because of field tillage timing versus planting date differences between corn and soybeans; however, some were planted to corn and oats) and 3) red or diffuse red - the majority of these fields were pasture and alfalfa, however, a few of these fields were later plowed and planted to corn or soybeans. This is noted because definite problems may arise when digital analysis procedures are employed, depending on the classification system used. Visual analysis of the field colors indicated on miniadcol produced color infrared renditions using July 2, 1973 ERTS-1 imagery revealed to some extent the crop seasonal development as the corn and soybeans progressed to diffuse red and red color responses. Oats fields followed this same pattern and this point will be noted as a digital classification problem later in this section.

The multi-date, multi-spectral false color rendition was produced in attempts to accentuate drainage patterns in the Ames area. These examples are shown in Figs. 26 and 27. The latter is a close-up. These results suggest that it may be appropriate to use the miniadcol as a preliminary tool in multi-spectral, temporal work employing digitized data analysis procedures. For example, registration of winter-time MSS7 (Fig. 22), springtime MSS7 (Fig. 10), summertime MSS7 (Fig. 9) and summertime MSS5 (Fig. 23c) should yield color separations between major land uses and crop types. We were unable to try this example because of time constraints.

f) Ames, Iowa flightline - preliminary digital analysis

Digital tapes corresponding to the May 10th and August 26th coverage of the Ames area (Figs. 9 and 10) were requested and received. The emphasis has been to determine the spectral response, as recorded on the digital tapes, for the major land uses and crop types in this area and to develop a temporal, multi-spectral classifier. In addition, considerable effort has been directed toward superimposition of the digital tape data in this area corresponding to these two dates. This aspect may be impossible on a theoretical basis when orbital differences, etc. are considered for these different dates, but we are basically attempting to achieve a more precise and controlled sampling system than is presently used in Iowa. With this in mind, close visual examination of black and white enlargements of the most detailed imagery of these data sets was initiated to locate places or objects on these enlargements which could be traced to a common location on each digital tape representing each date. This was necessary in order to determine if the scan lines from each data set were superimposable (e.g., only linear transformations were necessary). We decided to use major roads to accomplish this task (see Fig. 23a and 23d).

A regression analysis of the coordinates (scan line number and number position within a scan line) of data points selected along the road at both dates was completed. The slopes (b_1 term) from these two equations were very similar, 0.160 and 0.162. This indicated that x-y transformations would probably suffice as scatter was minimal.

The digital response of known field types was examined for a portion of the Ames, Iowa flightline. The first problem encountered was determining field boundaries. Even when black to white quite sharp boundaries were indicated on the ERTS-1 photographic enlargements, the responses as recorded on the digital tapes were not sharp in all cases. This is probably due to overlap of the scanner viewing element integrating the response between dissimilar fields. The sharpness of the digital data at boundaries depended on the degree of differences between the fields.

Further analysis of the temporal, digital data resulted in the following preliminary surface land-use-type classifier using May 10, 1973 MSS7 and August 26, 1973 MSS bands 5 and 7.

$X_{ij}\ (N_1, N_2, N_3)$

X = triplicate array representing the temporal, multi-spectral response for the same area on the surface

i = scan line

j = scan line element within a scan line

N_1 = digital response - MSS7, May 10, 1973

N_2 = digital response - MSS5, August 26, 1973

N_3 = digital response - MSS7, August 26, 1973

IF tests used in the classifier

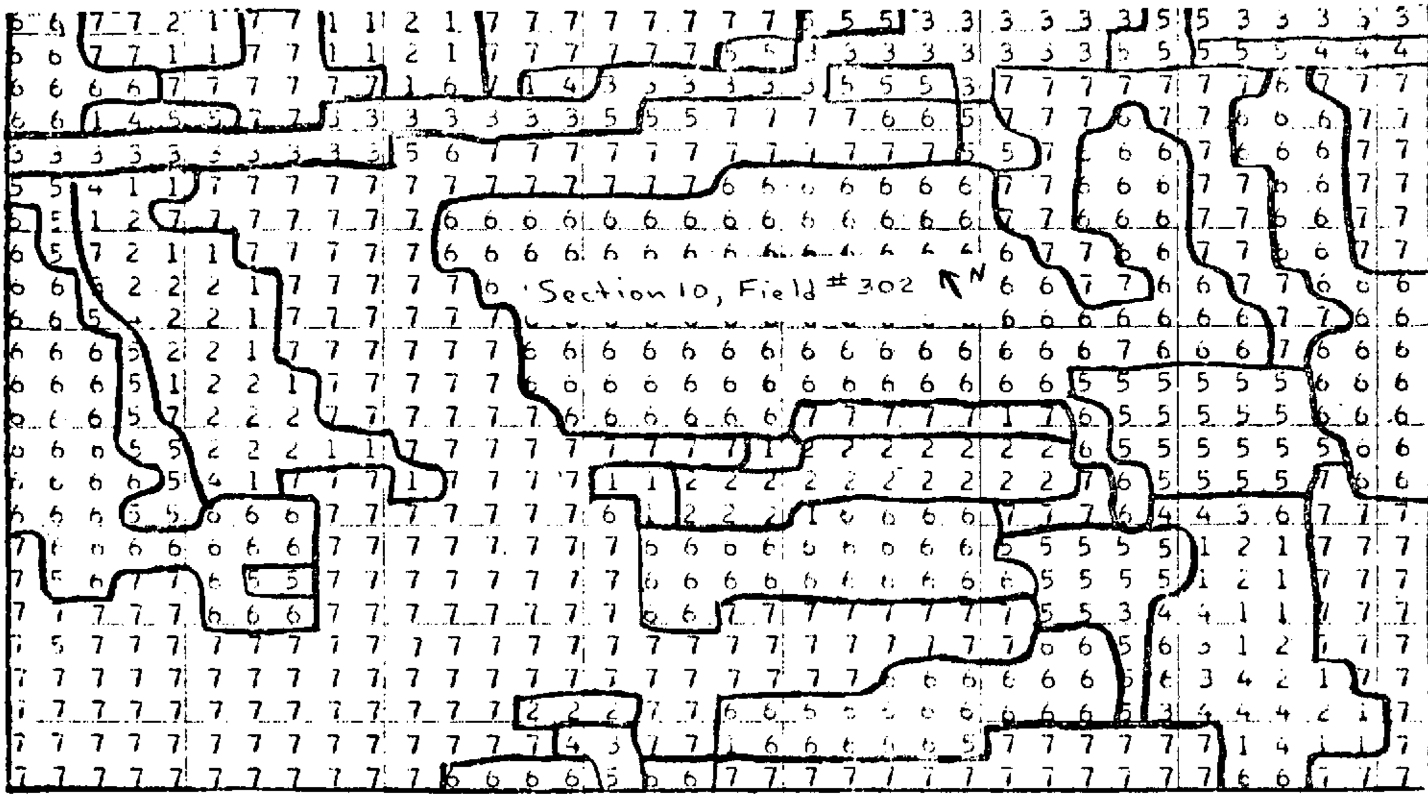
IF $N_2 \geq 20$	roads, towns, oats, alfalfa	IF N_1	≥ 25	alfalfa			
			19-24	towns and roads			
			≤ 18	oats			
$N_2 < 20$	forestry, corn, soybeans, water, pasture, alfalfa	N_1	≤ 5	water			
			6-22	corn, soybeans	IF N_3	≥ 30	soybeans
						< 30	corn
			23-29	forestry			
			≥ 30	pasture or alfalfa			

This analysis assumed that the triplicate of superimposed digital data elements represented the same area on the ground. This is, of course, a questionable assumption due to orbital and scanner restrictions at the two different dates. It is, however, the best estimate we can make from comparisons between digital readouts and corresponding black and white enlargments.

An example of computer output generated using this classifier is given in Table 13 for a small portion of the Ames, Iowa flightline. This area is also illustrated in Fig. 3 for interested readers with crop type listed in Table 11. Field #302 in section 10 is noted. No attempts have been made to rectify the data with respect to direction or for printer-output non-square characteristics. For these reasons Table 11 is not to scale. For strict inventory procedures using any good classifier, visual output may not be as importnat as the data summaries generated, except for ground truth checks.

We have not been able to fully evaluate this output at this time; however, problems which have been identified are: 1) possible failure to adequately superimpose digital data from different dates, 2) determination of field boundary digital response cutoffs, 3) possible failure to separate pasture and alfalfa fields and to separate oats and corn fields.

Table 13. Digital output using the temporal, multi-spectral crop classifier. The output includes a portion of the area illustrated in Fig. 3. The numeric-crop type correspondence is forestland (1), pasture or alfalfa (2), roads (3), alfalfa (4), oats (5), corn (6), soybeans (7), and water (8).



(These problems are not true for all fields, but depend highly upon ERTS-1 coverage at critical times throughout the crop growing season. For example, ERTS-1 coverage shortly after harvesting of alfalfa and oats fields would greatly aid their correct classification. This was observed frequently on other ERTS-1 black and white enlargements). and 4) difficulty in classification of fields which were plowed after the spring ERTS-1 coverage. In addition, output has not been generated which includes areas dominated by urban or forested areas. This part of the classifier will be tested later.

It must be emphasized that this part of the report is highly preliminary as this group started digital analysis quite late during the project duration. Other classification procedures will be used later in this continuing investigation. Acreage estimates from this output compared very well with known ground truth in selected fields. Therefore, if this procedure proves satisfactory, digital data is available over considerable portions of Iowa and could be used to compile ERTS-1 resolution-type land use surveys as existed in 1973.

g) General statements concerning 1973 growing season

Good ERTS-1 coverage was attained at several test sites in Iowa depending upon cloud cover and atmospheric haze. Temporal aspects of ERTS-1 imagery appear to separate most major crop types for Iowa. Visual techniques attempting acreage estimates are tremendously time consuming. Therefore, inventory must be achieved using digital techniques in concert with visual products, black and white single-date or miniadcol produced products including both single-date and temporal, multi-spectral. Digital techniques will have to be refined to remove some of the problems discussed in this report. For example, image and edge enhancement, statistical procedures in selection of specified crop type responses and other numerical digital procedures such as ratioing between MSS bands, etc. Even with these refinements, agriculture is a very dynamic system and good coverage at critical stages of crop development is of utmost importance.

Results and Discussion: Forestry Applications of ERTS-1 Imagery by George W. Thomson, Professor of Forestry, Iowa State University

1) Introduction

Forest managers are continually in need of cheap and reliable means for inventorying this resource. Both the acreage of forest land and the volume of fiber on the land are needed as a base for immediate and long range planning decisions. Unfortunately forest lands have the characteristics of being remote, difficult to traverse and of a value often lower than other lands.

Customarily forest lands are stratified into vegetational classes that reflect either value of the tree species, the cultural practices to be applied, or the relative density (volume) of the tree cover. Stratification has commonly been done through the use of black and white panchromatic aerial photographs of a scale between 1:12,000 and 1:20,000. Areas of these strata have been easily obtained by planimetering or some other appropriate procedure such as transecting or "dot-counting" with acreage templets. However, at the scales conventionally available a considerable number of photographs have to be handled for most forest surveys at a county, public forest or state survey.

The opportunity to use very small scale photographs was not afforded until the advent of ERTS-1. Foresters, more than most land managers, are therefore hopeful that cheap and reliable estimates of forest acreage will be soon forthcoming through the use of satellite imagery.

2) Objectives of Forestry Study

The declared objectives of this study have been to determine methodologies for interpreting forest cover and to test the reliability of these techniques.

An eight-township area along the Des Moines River in Boone County, Iowa was selected as the study site (see Fig. 10). The following studies were carried out:

I. A comparison of forest acreage estimates as derived from conventional aerial photos and enlargements made from ERTS-1 70 mm imagery.

II. Development of a technique for using a calibrated stage microscope for determining forest acreage directly on 70 mm imagery.

III. Applications of Double Meridian Distance procedures to determine acreage of an irregular body of water.

IV. Comparison of results of forest area determination by conventional photography; ERTS-1 September imagery and ERTS-1 January imagery where ground is snow covered (see Fig. 22).

V. Investigation of several cartographic, census, photographic and remote sensing media to trace the decline of forest area in Boone County, Iowa.

3) Procedures and Results

a) Area comparisons from conventional photos and ERTS-1 enlargements

Panchromatic black and white photographs taken in 1965 by the ASCS with 8 1/4 inch focal lengths at 1:20,000 scale and enlarged to 1:7920 with legal sections (640 acres) delineated and identified were obtained and ultimately considered as "ground truth". The uncontrolled mosaic, properly called a photo-index sheet, made of these same photos and reproduced at 1:63,360 was also utilized to compose the results of transect sampling at greater intervals but using the same photo imagery. A photographic enlargement from MSS5, September 18, 1972, imagery provides the third medium for measurement.

The ASCS enlargements of each GLO legal section were transected at 10 chain (660 feet) intervals and the acreage determined by multiplying the total length of transect falling on forest by the distance between transect lines. Usual forest inventory procedures were followed in classifying forest as any wooded unit of more than 200 feet in width, greater than two acres in area and having crown density of 10% (approximately) or greater. The acreages found by this method appear in Table 14 and can be considered as highly reliable for the year 1965 and probably less than 1% too large for the year 1972.

The ASCS mosaic was transected at mile intervals so that six lines were measured for each township. Acreages were obtained by determining the percentage of total measured line in each township that fell on forest land and then applying this percentage to the 23,040 acres found in the average township. See Table 14.

The photographic enlargement (1:226,284) of the satellite imagery was transected at 1 mile intervals. Because of the small scale, all measurements were done under a magnifying glass and the distances along each line falling on forest were measured with a micrometer bar (Abrams Height Finder) where the scale could be read to .01 mm. Acreages were found by two methods. Method A: The total length of line in forest was multiplied by the distance between transects. Method B: The percentage of transect line falling on forest was multiplied by 23,040 acres per township. See Table 14.

Table 14. Forest acreages as determined by several methods utilizing aerial photography and remote sensing. Boone County, Iowa. 5th P.M.

Township	ASCS Photos 1965 1:20,000	ASCS Photo Mosaic 1965 1:63,360	ERTS-1 Enlargement 1:226,284 "A"	ERTS-1 Enlargement 1:226,284 "B"
	- - - - - - - -	Acres	- - - - - - - -	- -
T85N R27W	5517	5687	4254	4385
R26W	1046	1025	1772	1701
T84N R27W	4833	5818	3395	3458
R26W	1718	1425	2796	2731
T83N R27W	1639	1444	517	533
R26W	5875	5407	6497	6311
T82N R27W	0	0	0	0
R26W	4748	5192	4718	4653
Total	25376	25998	23949	23772

b) Classification of forest vs. nonforest and the determination of acreage of forest by use of a mechanical stage microscope.

An attempt was made to determine forest acreage directly from the 70 mm diapositive provided to collaborators by NASA. The test imagery was that from ERTS-1 of September 17, 1972, MSS5. The study area was the seven-township portion of Boone County, Iowa emcompassing the Des Moines River drainage.

Aligning the diapositive on the calibrated traversing stage of an AO microscope under 40 X enlargement the sample area was transected in an E-W direction through the center of each tier of six sections. For example, sections 1-6 would be sampled by one transect as would sections 7-12 etc. The forested portion of each transect was measured in millimeters as read from the calibrated vernier scale on the slide stage. These distances, when divided by the total length of each transect, resulted in an estimate of the percentage of land in forest cover.

To evaluate the microscope procedure for use in forest sampling these percentages were compared by regression analysis with transects taken from 1:7,920 enlargements of conventional ASCS photographs taken in 1965. The information taken from the enlargements may be assumed to be equivalent to ground truth.

Utilizing the 42 transects from each of the two procedures the regression coefficients and appropriate error statistics were computed.

$$Y = .0219 + 1.1636\ X \qquad r = .7997^{**}$$

$$s_b = .1382 \qquad t_b = 1.1838^{ns}$$

Y = forested land % (microscope)
X = forested land % (ASCS photos)

$$s_{y \cdot x} = .0141 \qquad t_a = 1.5532^{ns}$$

$$t_{dep.} = -3.5272^{**}$$

The linear correlation coefficient, r, was significant at $p = .05$; the slope coefficient did not differ significantly from 1.00; the Y-intercept did not differ significantly from 0. ($p = .05$) From the foregoing it can be assumed that the forested percentage of six sections of land would not differ significantly between methods for determining it, i.e. microscope on small scale ERTS imagery vs. large scale conventional photography. However, the forested portion of the 252 sections analyzed by the microscope technique was 20.49% as opposed to 15.73% found from aerial photographs. This overall difference between means was significant ($p = .01$).

Because of the physical problems of enlargement of ERTS-1 imagery with the attendant loss of resolution and difficulty in carrying out area measurement by either mechanical planimeters or by point sampling it is believed that direct transecting with a low power microscope provides a practical solution to the problem of extensive forest sampling.

It is assumed that September, MSS5 imagery did not provide sufficient contrast in reflectance between forest and pasture or open woods and that the use of imagery from other spectral bands or calendar dates will be more successful. This assumption will be tested and presented in subsection d.

c) Area determination of a reservoir by use of a low power microscope, 70 mm imagery and the Double Meridian Distance (D.M.D.) procedure.

As the satellite view of a reservoir provides a sharply delineated boundary on the 70 mm ERTS diapositive it seems logical that the traversing, calibrated stage of a microscope can be utilized to determine the conventional latitudes and departures called for in finding the area of a closed traverse by conventional surveying methodology.

The recently completed Big Creek Reservoir in Polk County, Iowa is clearly visible on the MSS5 and/or 7 imagery of August 13, 1972, September 17, 1972, April 3, 1973 and May 9, 1973. This reservoir was used to study the feasibility of the D.M.D. technique.

Procedure:

1. Orientation to north is not critical to this technqùe but the imagery was aligned so that transect lines were essentially E-W.
2. Transect lines were set .15 mm apart (a distance of approximately 1,600 ground feet). X-Y coordinates for the lake boundary were read.
3. Starting one-half interval from the east edge of the dam, the X-scale values were recorded adjacent to the Y-scale values for that transect. These paired values were kept in order in the same sequence that a surveyor would employ if on the ground.
4. Upon completing the traverse the ΔX and (Y) (ΔX) computations were made and the area of the figure was computed in square

millimeters. (Refer to any standard text on land survey). See example below.

5. The scale of the imagery must be carefully determined. In this test two clearly locatable and well-mapped points approximately ten miles apart were used to determine the scale for each set of imagery.

6. The acres per square millimeter conversion was determined for the average scale and the reservoir acreage determined.

Table 15. Computation of acreage of Big Creek Reservoir, Iowa.

Imagery Date	Scale, ft/mm	Average A./mm^2	Area of Image, mm^2	Area of Reservoir Acres D.M.D. Method
Aug. 13, 1972	10,877	2,785	.1625	453
Sep. 17, 1972	11,135	2,785	.1645	458
Apr. 3, 1973	11,021	2,785	.2230	621
May 9, 1973	11,022	2,785	.2525	703

EXAMPLE OF DOUBLE MERIDIAN DISTANCE CALCULATION

Corner, i	Y Coordinate	X Coordinate	(X)	(Y)(X)
0	113.90 mm	22.95 mm	+.10 mm	+11.39 m^2
1	114.05	22.95	-.05	- 5.70
2	114.20	23.00	-.05	- 5.71
⋮	⋮	⋮	⋮	⋮
15	114.20	23.15	+.10	+11.42
16	114.05	23.05	+.20	+22.81
				Sum = - .329 mm^2

Area, mm = .329 mm^2 2 = .1645 mm^2

Area, acres = (.1645 mm^2) (2,785 Ac/mm^2) = 458 acres

While the procedure seems to meet consideration, the Corps of Engineers records indicate that the reservoir reached spillway level in November 1972 at which time the projected area taken from a 1:2400, 5-foot contour internal topographic map was estimated to be 890 acres. The April and May 1973 imagery did clearly show that the acreage was vastly increased due to flooding. Further study of the technique is suggested.

d) Forest area determination from 70 mm ERTS-1 imagery, September and January vs. area from ASCS 1:7920 photography

Previous attempts to separate forest from pasture and cropland by use of spring, summer and fall 70 mm format imagery from ERTS-1 were unsuccessful in the eight-township test area in Boone County, Iowa.

However, a final attempt to determine forest acreage using the January 4, 1973 imagery has been found to be highly successful. All four available bands appeared to be equally usable although the quantitative evaluation was finally done with band 5. The presence of snow cover aided immeasurably by screening out the low growing brushy areas and the wooded pastures that lie adjacent to the hardwood forests of Iowa.

The similarity in spectral reflectance between forest and pasture had caused all previous forest identification attempts to fail due to sizable over-estimation of forest cover. As Table 16 shows there is excellent correlation between the winter imagery as measured under the stage microscope and the large scale panchromatic photography.

As the contrast between the snow-covered background and the dark forest is extremely pronounced it seems likely that winter imagery provides the best possibility for forest boundary delineation. Direct analysis from the computer tape therefore, would seem to provide a most efficient technique for production measurements as there are few grey levels, the contrast at the borders is extremely pronounced and the 25-30 transects per mile that are provided by electronic scanning provide much higher precision than does the one transect per mile that was used in this test and would surpass the ten transects per mile used in the photographic check. Subsequent analyses will be made from the data tapes of January 4, 1973 to determine the potential of automatic area compilation.

Table 16. Acres of natural timberland in eight townships of Boone County, Iowa as determined by 1:7920 aerial photographs and ERTS-1 70 mm imagery.

Township	ASCS Photos 1:7920 1965	ERTS-1 Band 5 January 4, 1973 70 mm imagery	ERTS-1 Band 5 September 18, 1972 70 mm imagery
	- - - - - - - - Acres	- - - - - - - -	- - - - - - - -
Pilot Mount	5517	4834	7416 ± 2481*
Dodge	1046	682	707 ± 828
Yell	4833	5334	5872 ± 3270
Des Moines	1718	1734	2998 ± 1540
Marcy	1639	1848	1834 ± 1617
Worth	5875	5265	6295 ± 1630
Peoples	0	0	0
Douglas-Cass	4748	5690	4749 ± 3031
Total	25376	25387	32064 ± 7164

* mean and standard error, p = .05
n = 6 for townships and n = 42 for total.

e) Combinations of data sources for the historic analysis of forest land patterns.

It has become an article of faith that Iowa had 6,680,926 acres of woodland when the state was surveyed for settlement in the mid-19th century and that more than 60 percent decrease in forest land has taken place. However, intensive research of the records for a test county (Boone) indicates that the vagaries of observation, definition of the term "forest", and sampling procedures obscure both the amount of timber and its change. ERTS-1 imagery may provide a more precise record of the state's woodlands than has so far been obtained.

The following table provides a comparison between past and present inventories of the forests of Boone County, Iowa (see Fig. 29).

Table 17. Acres of natural timberland in Boone County, Iowa.

Township	G.L.O. Plat 1832-1859	Natural Timber 1874 Census	Andreas Atlas 1875	Iowa State Planning Board 1933	ASCS Photos 1965	ERTS-1 Enlargement MSS5 9/18/72	ERTS-1 70 mm MSS5 1/4/73
	Acres						
Grant	0	36	0	0	0	0	-
Pilot Mound	11605	705	9160	6451	5517	4254	4834
Dodge	2037	2569	2406	4838	1046	1772	682
Harrison	528	486	794	1152	340	-*	-
Amaqua	0	264	0	230	0	0	-
Yell	11011	2261	9370	7603	4833	3395	5334
Des Moines	5446	3299	4250	6912	1718	2796	1734
Jackson	798	280	768	3226	516	-	-
Beaver	0	15	179	230	57	-	-
Marcy	2984	2125	2867	4147	1639	517	1848
Worth	13314	3775	11766	7142	5875	6497	5265
Colfax	0	429	0	0	0	0	-
Union	1349	919	947	922	506	-	-
Peoples	0	528	0	0	0	0	0
Douglas-Cass	12294	5762	9754	8179	4748	4718	5690
Garden	92	97	205	461	115	-	-
TOTAL	61458	23550	52466	51493	26910	(23949)**	(25387)
Drainage							
Des Moines R.	58691	21024	49573	45272	25376	23949	25387
Beaver Creek	1349	1234	1126	1382	563	-	-
Squaw & Onion Cr.	1326	766	1562	4378	856	-	-
Big Creek	92	526	205	461	115	-	-

* - indicates that no measurements were attempted

** ( ) indicates a partial sum

f) Conclusions and recommendations

While species identification does not look very promising from the visible and near IR wavelengths this may not be as serious as first thought. The delineation of forest from non-forest seems most promising. Further comparisons of the 4 MSS bands now available with false color IR photography should be helpful.

Certainly the monitoring of floods and charting water bodies is already realistic.

Spectrophotometer analysis as a precursor to density slicing and direct display of output from the digital tapes has not yet been seriously explored at this station. Considerable likelihood of success can be anticipated from use of winter-time imagery.

The experience with satellite imagery has been most stimulating. Avenues for further exploration of the possibilities of this imagery are limited only by the imagination of those who must manage extensive areas of land.

Results and Discussion: Soil Association Mapping using ERTS-1 Imagery by Tom E. Fenton, Professor of Agronomy, Iowa State University.

1) Discussion of the state ERTS-1 springtime mosaic

The soil association map shown in Fig. 28 was constructed using the state mosaic (see Fig. 11). Imagery used to construct the mosaic was MSS band 7, acquired in May and June of 1973. Areas of the state to be used for intensive row-crop production had been cultivated and lacked significant vegetative growth during this time period. These areas are very light colored on the imagery and are closely related to the soil association lines. Other areas are varying shades of grey, except bodies of water which are white.

Soil association lines were photographically transferred to the ERTS imagery from an available map prepared using another base. A comparison of Fig. 29 which shows the original forest cover in the state of Iowa at the time of the original land survey to the ERTS base soil association map shows the high correlation among imagery response, vegetative cover and soil association areas.

Selected soil association areas and their characteristics as they relate to the patterns on the association map will be briefly discussed in the following paragraphs.

a) AGH (Adair-Grundy-Haig) and ASE (Adair-Seymour-Edina)

These areas have a thin loess cover over a dissected till plain. The Seymour and Grundy soils have developed in loess and have dominant slope gradients of 2-9 percent. Edina and Haig soils occur on broad upland flats and have also developed in loess. Slope gradients range from 0 to 2 percent. The loess buries a part of the glacial till landscape. Adair and Clarinda soils are exhumed paleosol and are the most stable parts of the old buried landscape. At elevations lower than the areas where the paleosols outcrop, hillslopes are cutting into deposits of Kansan glacial till and in some areas, Nebraskan till.

According to the Conservation Heads Inventory, more than one half of the area is used for cropland. Corn and other feed grains are the principal crops grown. Areas used for cropland are primarily the loess areas and the less steeply sloping till areas. About one fourth of the area is in pasture and about 10 percent is in woodland. The lighter colored areas represent essentially bare fields with little or no vegetative growth. The darker areas represent areas of vegetation and in these areas the land use would be primarily mature pastures, pasture and hay, and/or timber. Because of the limitations related to topography, the patterns, also, are a reflection of the landscape characteristics of the area.

b) CNW (Clarion-Nicollet-Webster)

This soil association area occurs in north central Iowa and occupies all or parts of 29 counties. It extends northward into Minnesota. In Iowa, this association is the most extensive soil area occupying about 20 percent of the state. In general, the topography is nearly level to gently sloping. Closed depressions are common in the area and result from the lack of development of an integrated drainage net on the geologically young glacial deposit. Native vegetation of the area was primarily prairie grasses. The most extensive areas of trees border the major streams. The pattern of tree growth is shown clearly along the Des Moines River, which is approximately in the center of the area. Comparison of the ERTS-1 imagery with the original forest cover map of Iowa shows the forest cover still present in the corner joining Winnebago, Worth, Hancock and Cerro Gordo counties.

c) GPS (Galva-Primghar-Sac)

This association occurs in all or parts of 11 counties in northwest Iowa and covers about 7 percent of the state. Loess deposits cover most of the upland. Loess thickness decreases in the eastern part of the area and is thickest in the western and southwestern parts. Wisconsin age glacial till outcrops near the base of some slopes. Native vegetation was prairie grass.

About 80 percent of this soil association is used for cultivated crops. The long, gentle, uniform slopes of the area are well suited to intensive row crop production, but the average annual rainfall of less than 28 inches limits yields in many years.

d) KFC (Kenyon-Floyd-Clyde)

This soil association area occupies about 10 percent of the state and occurs in 21 counties in northeast Iowa. General topography of this area is nearly level to gently rolling. The landscape is an erosion surface complex cut into Kansan and/or Nebraskan till. Swell and swale topography is common in many parts of the area. Native vegetation was primarily prairie grasses, but trees are still present along stream valleys and in other areas. More than 75 percent of the area is in cropland with corn and other feed grains as the major crops. This intensity of land use is shown by the light color pattern of MSS band 7 on the association map.

e) TM (Tama-Muscatine)

The Tama-Muscatine soil association occurs in four separate areas in central and east-central Iowa. Total area occupied by this soil association is about 7 percent of the state. Loess thickness varies from approximately 5 to 25 feet in the area. A high percentage of the soils occur on nearly level to gently sloping topography in fairly large uniform areas. Intensive row crop production is a characteristic of much of the area. The soils in the area are some of the most productive in the state. The large area of TM east of the Cary Lobe (CNW) the topography consists of rounded gently sloping divides, moderately to sloping side slopes, and narrow valleys. The effect of this topography on land use is readily apparent when this area is compared to the nearly level to gently sloping areas to the north in the same soil association area.

2) Soil association mapping in central Iowa using ERTS-1 imagery.

The enlargement of the ERTS-1 imagery to a scale of 1:250,000 is shown in Fig. 30. More detailed soil association lines for Boone county in central Iowa are superimposed on the imagery. The Des Moines River flows north to south through the approximate center of the county. The darker areas on the valley walls and on uplands adjacent to the stream are due primarily to the forest cover in these areas. Note the correspondence of this imagery to the original forest cover, Fig. 29.

3) General recommendations

From the example cited, I conclude that the ERTS-1 imagery acquired at the proper season of the year is an excellent base for soil association maps at scales that range up to 1:250,000. Also, land use in general terms can be interpreted from the imagery with a minimum of effort. For example, the most extensive area prepared for row-crop planting in May-June 1974 are generally in the northern half of the state. More specific interpretation concerning the types of crops and their extent is included in another part of the report.

Analysis of underflight imagery obtained as a part of this project are in progress. The imagery is being evaluated in terms of its use in operational soil survey programs. Results will be reported at a later date.

Results and Discussion: Diseases of corn - ERTS-1 Monitoring 1973 by A. Epstein, Associate Professor of Botany and Plant Pathology, Iowa State University.

1) Independence, Iowa test site

Corn plots (T and N cytoplasm) were established at Independence, Iowa and were inoculated with *Helminthosporium maydis* (T) in July. Spatial resolution of the ERTS-1 satellite was not sufficient to detect these plots. In addition, cloud cover greatly limited imagery acquisition for this area. Disease development reached stage 3 (on a scale of 0 to 5). Yellow leaf blight had also caused an equal amount of foliar damage by that time. Differences between T cytoplasm and N cytoplasm plants were readily apparent on the ground and on the underflight imagery (see Fig. 5 for 1972 growing season). However, incidence of stalk rot was much higher (20%) in T cytoplasm than in N cytoplasm plants (5%) so inferences specifically directed to Helminthosporium maydis detection are limited to these ground and underflight data.

APPENDIX A

Project, trace, cut and weigh acreage estimate procedures used for 1972 ERTS-1 imagery.

1) Miniadcol produced color slides: Color slides were taken of the miniadcol screen on which the ERTS-1 imagery was projected. The color filter used and wavelength selections were such that maximum contrast could be detected by the eye. The slides were then projected on the wall to attain appropriate enlargements. Ground truth areas were located and an identification scheme was established. By knowing which color filter and which ERTS-1 wavelength was used, it was possible to determine the response expected of various crop types. After a given color was established as corresponding to a particular crop type, acreages were obtained by outlining the designated color areas. These areas were then cut, weighed and converted to acreages through an adjacent calibration strip.

2) Opaque projected black and white prints: This method utilized the less sophisticated equipment; however, as shown in this report, this method yielded quite good results. This method involved the projection of an individual black and white print (MSS5 and MSS7) onto a flat surface. Areas corresponding to a particular field type were outlined, cut, weighed and converted to acreages. The signature for specific field types was established from the results of Figure 6. It was necessary to superimpose two wavelengths sequentially on the same tracing as signature analysis had indicated that single-band discrimination was not possible by visual analysis of enlarged black and white prints for most fields. It had been determined that a few fields yielded a dark response on both enlarged prints of MSS7 and MSS5, but that none of these fields were soybeans. Therefore, dark fields on MSS7 were outlined and MSS5 was projected onto this trace. Any dark areas on MSS5 corresponding to dark areas on MSS7 as indicated by the original outline were double outlined and were not cut out.

The resulting areas outlined were then considered to be soybean fields in this example.

3) Photomicrograph method: This method is quite similar to the opaque projector method except for the form in which the imagery was projected onto the screen. Photomicrographs were taken of the 70 mm positive ERTS-1 transparencies (both MSS5 and MSS7) using a low power microscope. This method was attempted because there were heating problems using the opaque projector over long periods of time. In addition, we were attempting to increase the resolution of the projected imagery. When used for acreage analysis, the projected imagery on the screen was treated as with the opaque projector method, including superimposing the two ERTS-1 wavelengths. It should be noted that, as with the opaque projector method, difficulty is encountered when attempting to register one wavelength projection on the trace of another. In both methods the degree of difficulty depended upon the quality of the ERTS-1 imagery and the distinctness of field spectral response differences on the imagery.

4) Photocut method: The photocut method is similar to the previous methods discussed in that only single wavelengths were used as data at one time. No projectors or tracing were necessary. Black and white prints were enlarged to a scale which was workable and at the same time did not allow complete loss in image resolution. Area estimates were obtained by cutting fields from the print corresponding to the previously established spectral signatures. Combinations of two wavelengths were used for the determination of fields with multiband spectral signature discriminations. This was accomplished by overlying the two prints onto an intense light table. Very good registration is possible using this technique and this method has the advantage of being able to indicate exactly what areas have been included in the estimate. Also, once one crop has been cut, another

signature can be designated by tracing the cut out areas of one imagery onto another image.

5) Another method used in the Ames flightline was as follows. The imagery was projected onto graph paper (10 lines/2.54 cm) and dots were placed at the intersection of lines on the graph paper which indicated a particular crop signature. The summation of dots placed was then converted to acreage estimates.

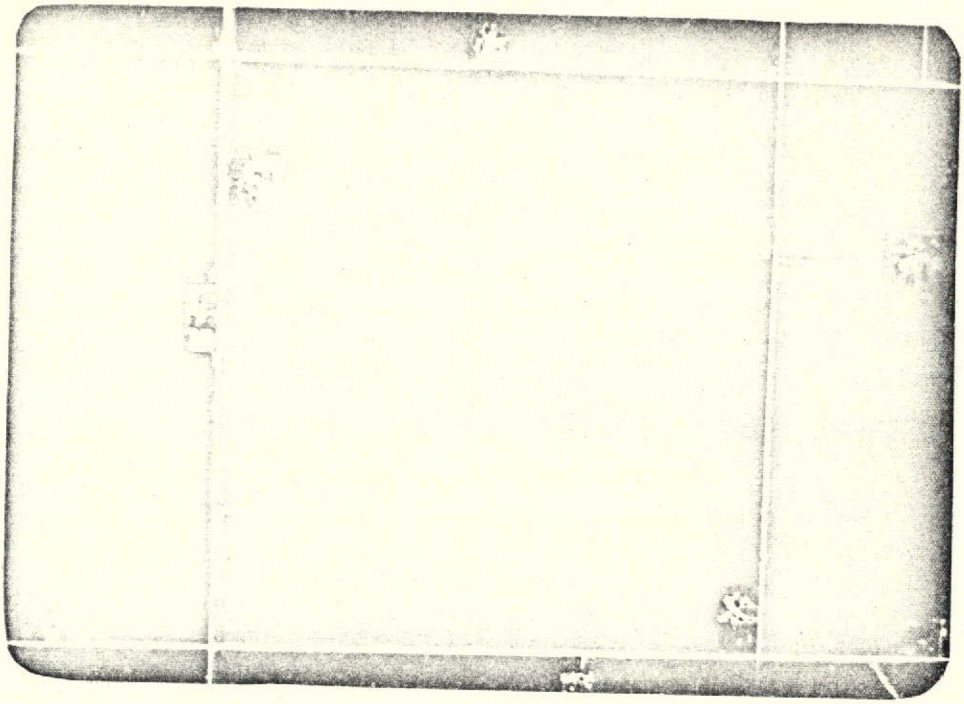


Fig. 1. A color print depicting a portion of the O'Brien County, Iowa flightline: color infrared - August 1973.

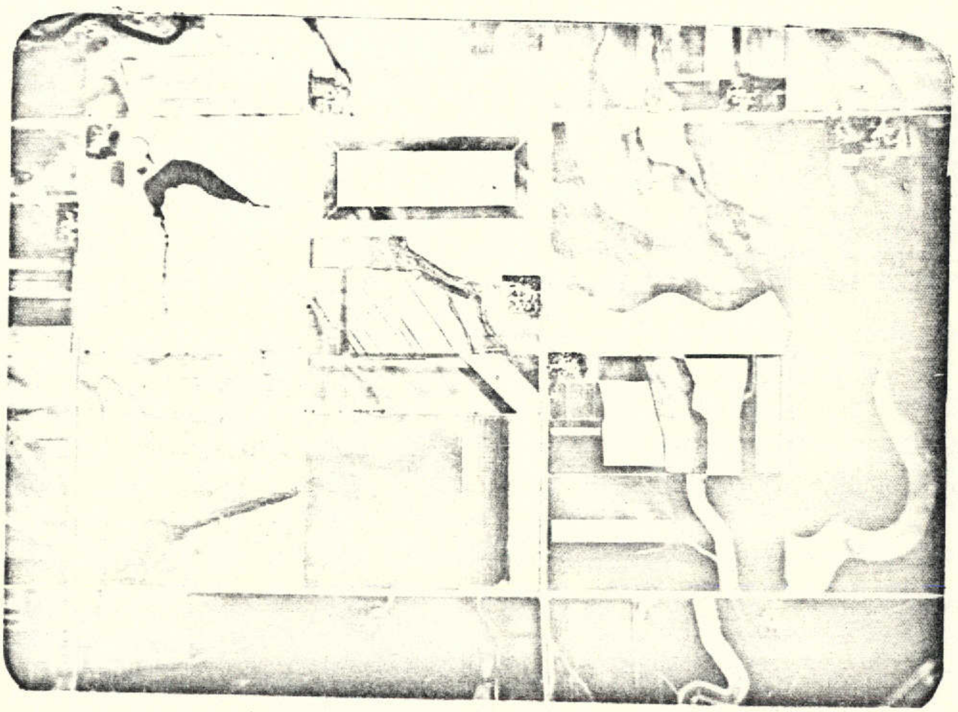


Fig. 2. A color print depicting a portion of the Doon, Iowa flightline: color infrared - May 1973.

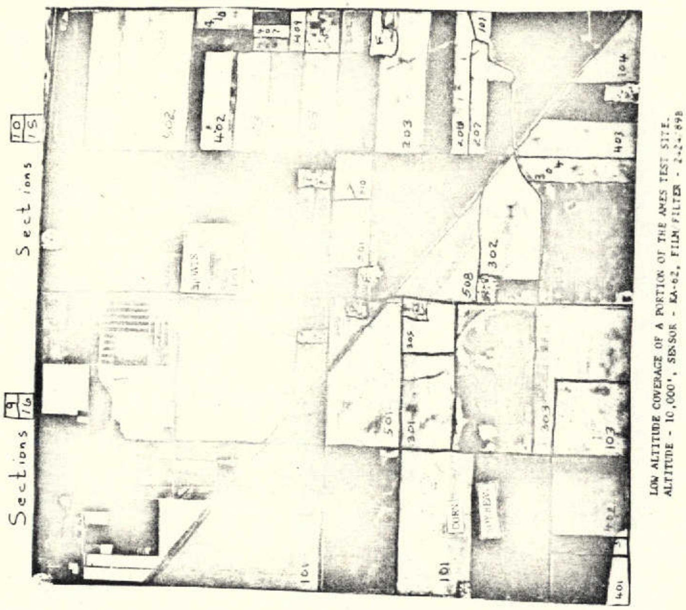


Fig. 3. A black and white print depicting a portion of the Ames, Iowa flightline: #89B filter - August 1973. Section and field numbers are given with field types listed in Table 11.

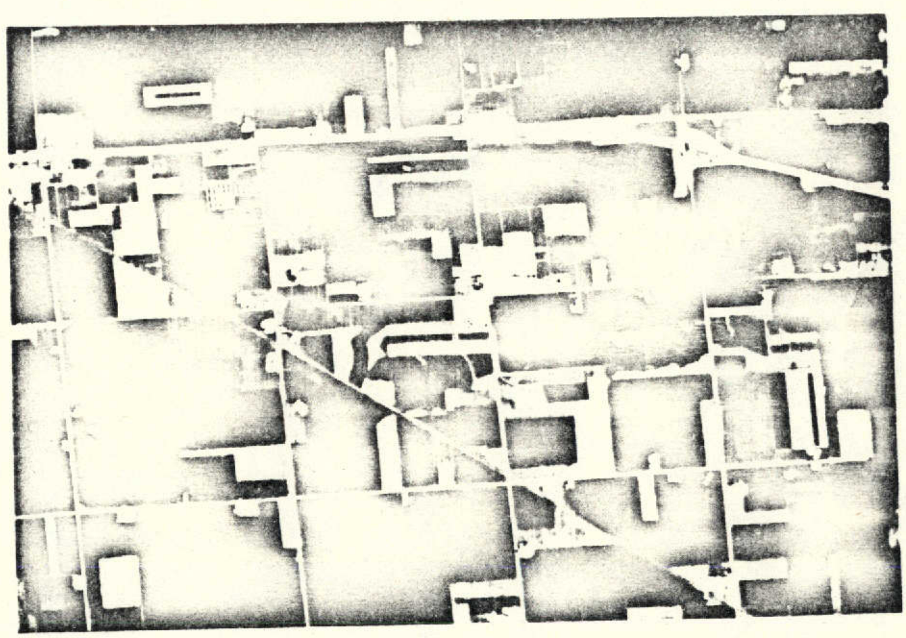


Fig. 4. A black and white print depicting a portion of the Ames, Iowa flightline: RS-14 thermal scanner - August 1972.

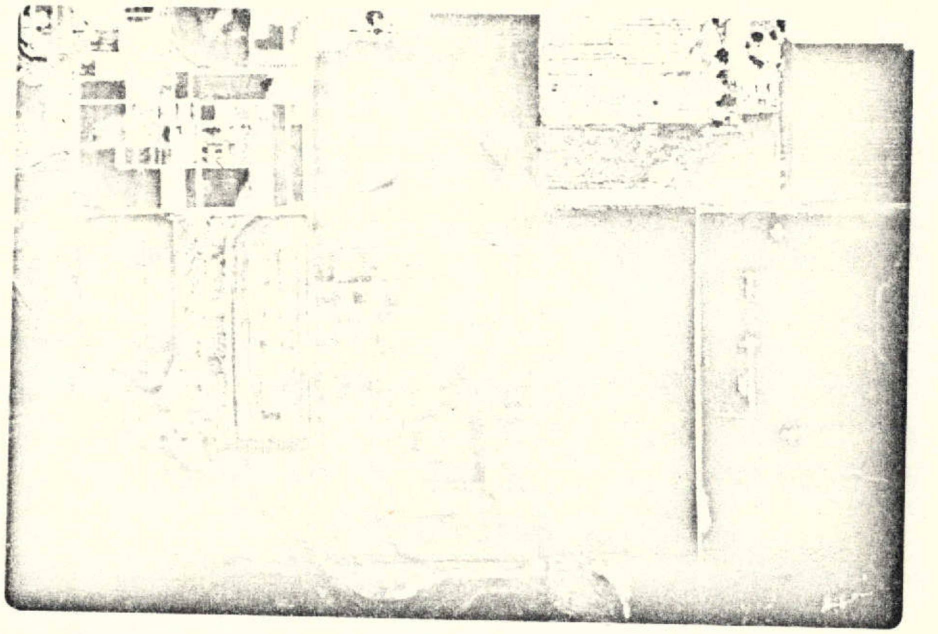


Fig. 5. A color print depicting a portion of the Independence, Iowa flightline: color infrared - August 1972.

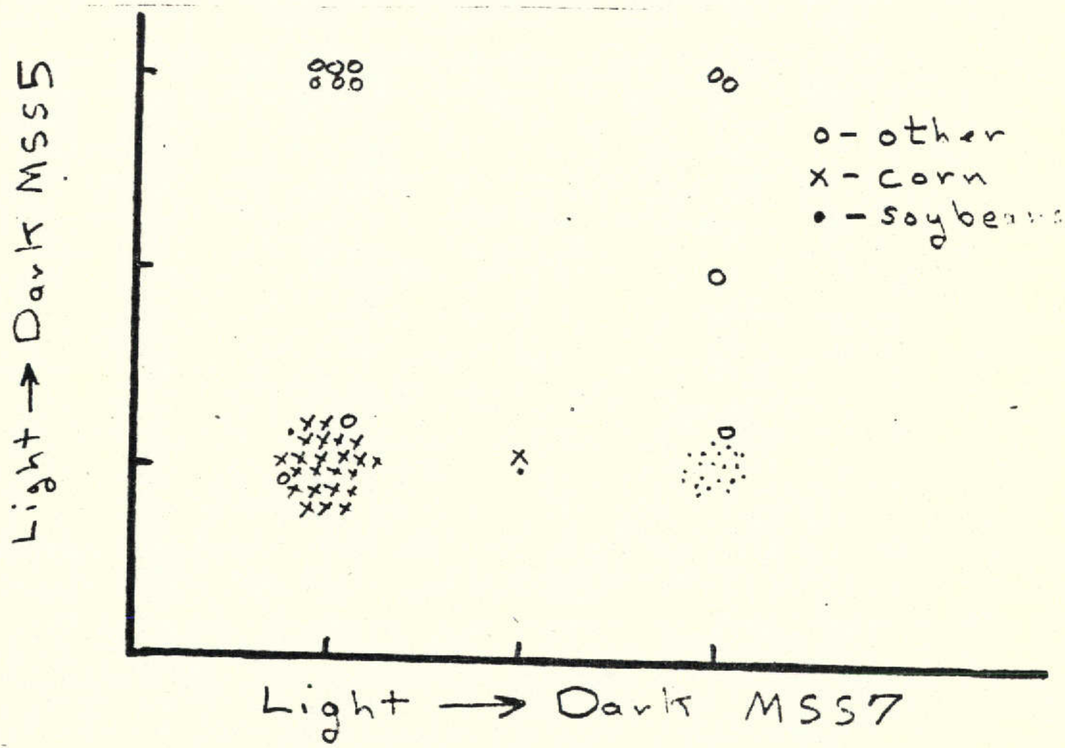


Fig. 6. Cross tabulation plot of known field visual responses as viewed on black and white enlargements of MSS bands 5 and 7 covering the Ames flightline on August 13, 1972.

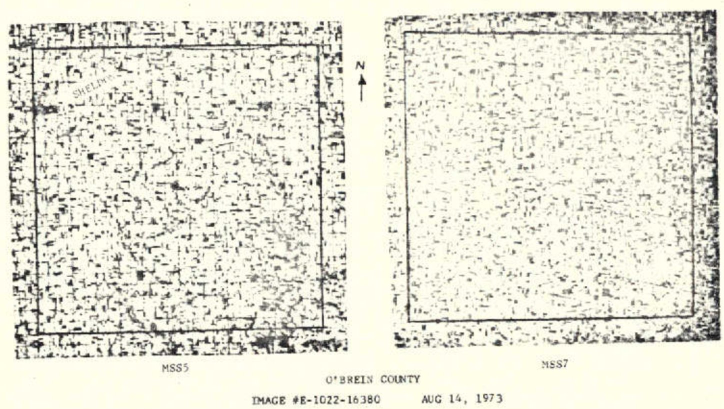


Fig. 7. Black and white enlargement of ERTS-1 imagery (August, 1972) covering O'Brien County, Iowa. MSS bands 5 and 7 are shown.

Fig. 8. Black and white enlargement of MSS5 ERTS-1 coverage of northeast Iowa on September 11, 1973. Dark areas are towns, roads and some stubble and plowed fields. Grey areas are generally fields with actively growing vegetation. Light areas correspond to heavily wooded areas.

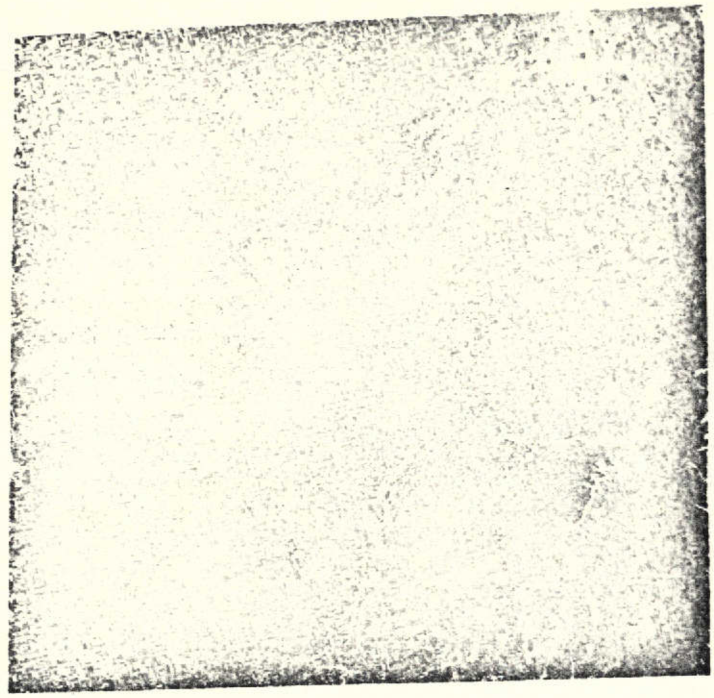


Fig. 9. Black and white enlargement of MSS7 ERTS-1 coverage of central Iowa on August 26, 1973. Dark areas are mostly soybean and uncut alfalfa fields. Grey areas correspond to towns, forestland, corn, pasture and oats fields. White area indicates bodies of water and bare soil.

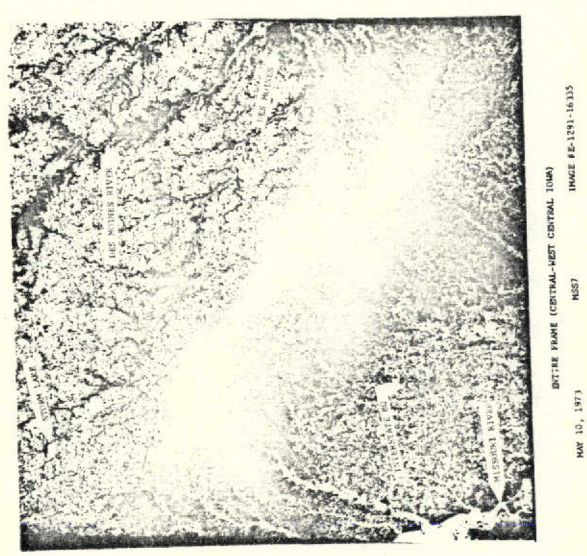


Fig. 10. Black and white enlargement of MSS7 ERTS-1 coverage of central Iowa on May 10, 1973. Dark areas are mostly actively growing vegetation, towns and some roads. Grey and light areas correspond to fields at various stages of early season tillage. White areas indicate water, lakes and rivers.

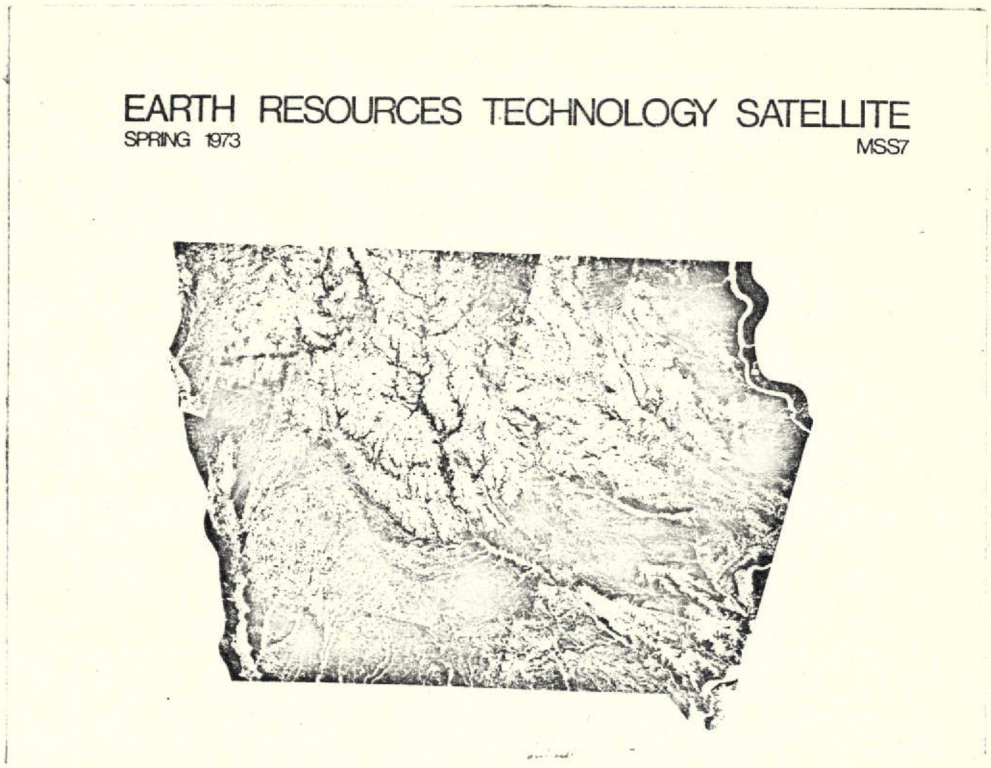


Fig. 11. Black and white enlargement of MSS7 ERTS-1 imagery covering Iowa during May and June of 1973 assembled into a state mosaic. See Fig. 10 for general land use-black and white response correspondence.

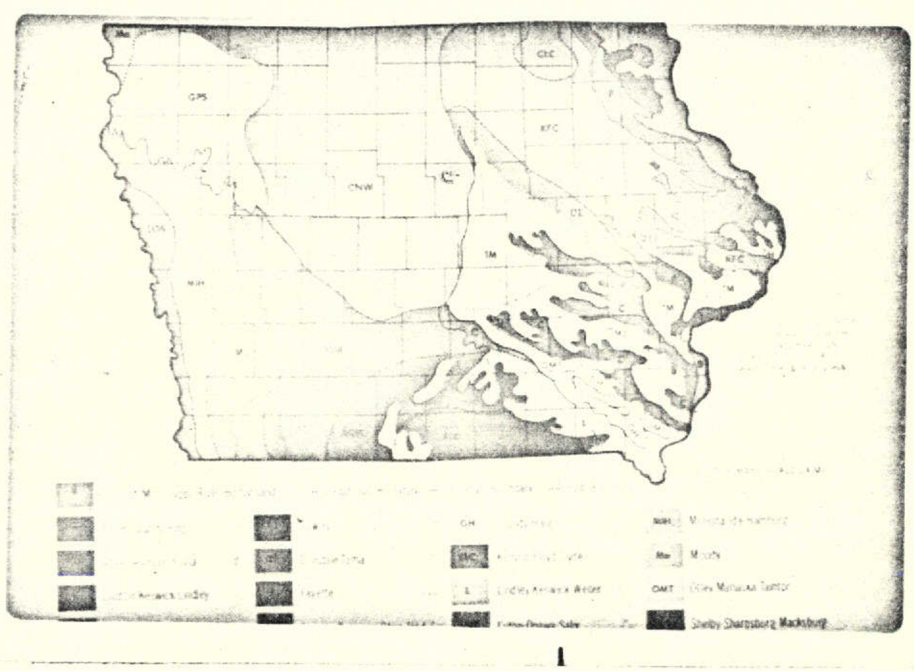


Fig. 12. Color print depicting the known soil associations of Iowa.

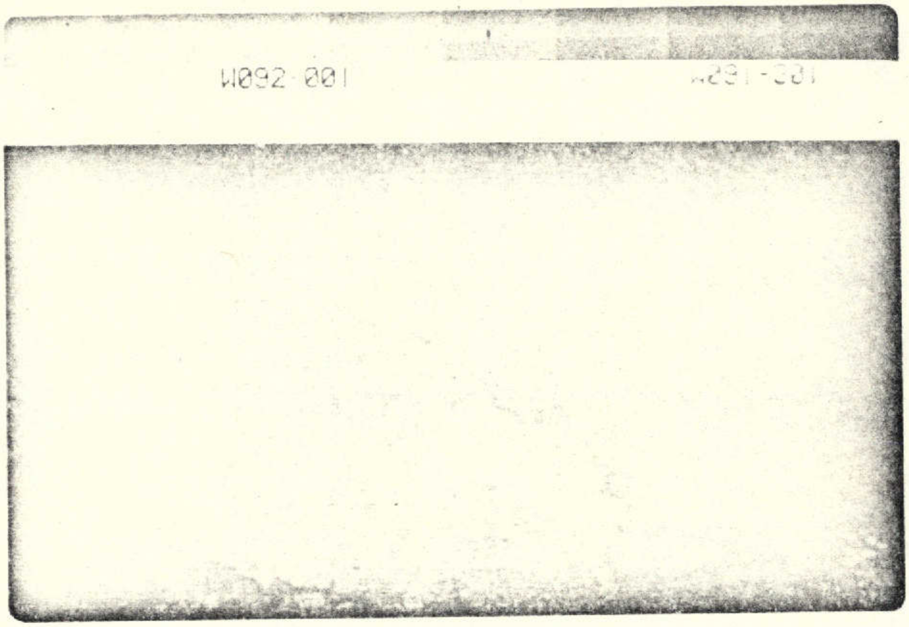


Fig. 13. A miniadcol produced color infrared rendition of ERTS-1 imagery covering a portion of the Independence, Iowa flightline in June, 1973. General color responses are discussed in the text.

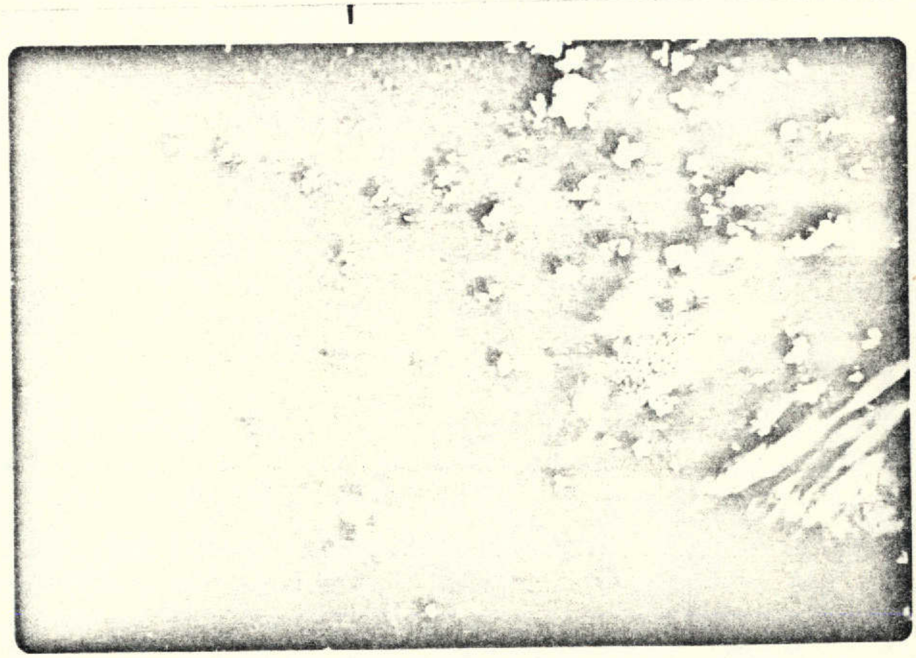


Fig. 14. A miniadcol produced color infrared rendition of ERTS-1 imagery covering the Doon, Iowa flightline on May 11, 1973. General color responses are given in Table 8.

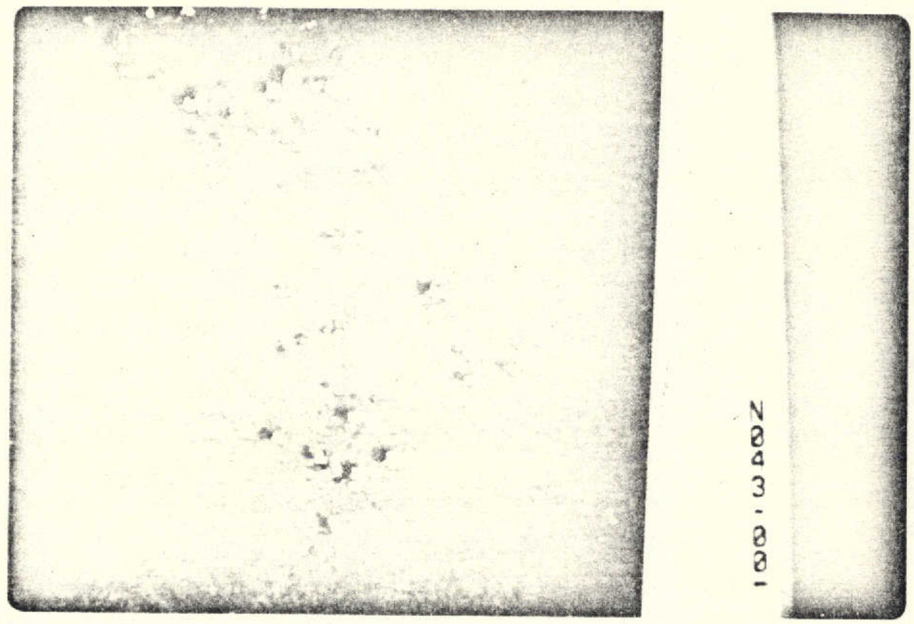


Fig. 15. A miniadcol produced color infrared rendition of ERTS-1 imagery covering the Doon, Iowa flightline on May 30, 1973. General color responses are given in Table 8.

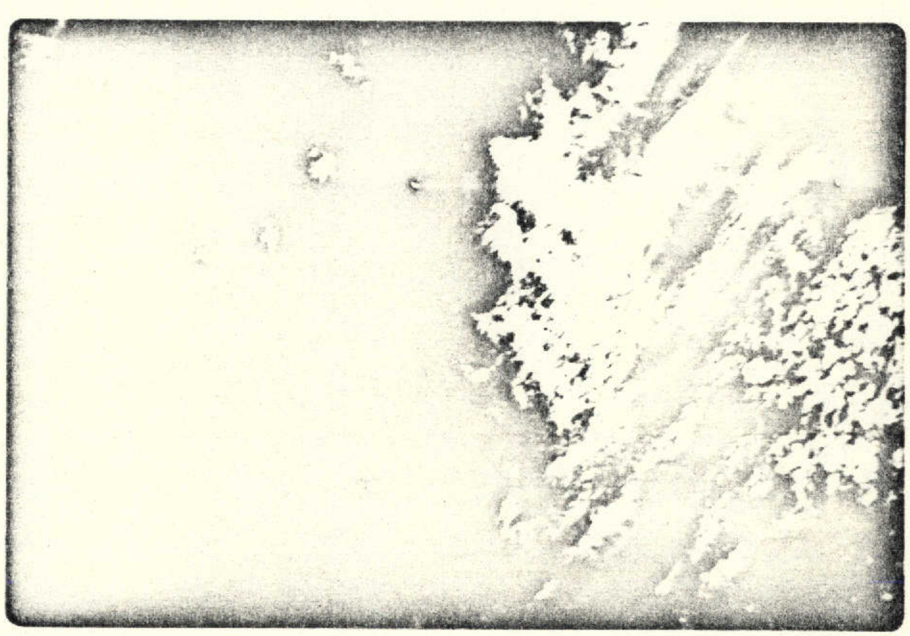


Fig. 16. A miniadcol produced color infrared rendition of ERTS-1 imagery covering the Doon, Iowa flightline on June 16, 1973. General color responses are given in Table 8.

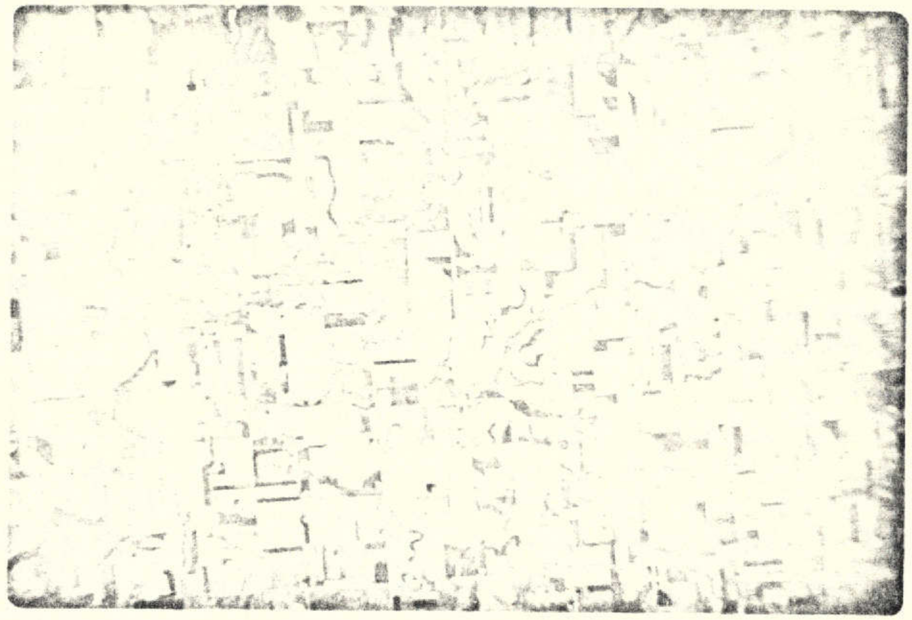


Fig. 17. A regular color print produced from a portion of Skylab imagery generated during June of 1973 covering the Doon flightline. This imagery was acquired with the S 190 B earth terrain camera.

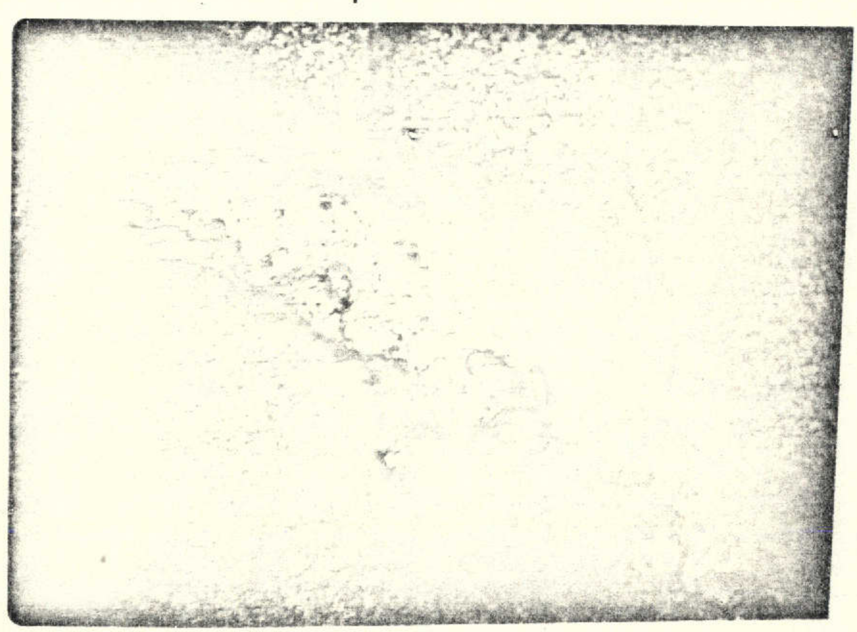


Fig. 18. A miniadcol produced color infrared rendition of ERTS-1 imagery covering portions of the Missouri River bordering Iowa, Nebraska and South Dakota during the spring of 1973.

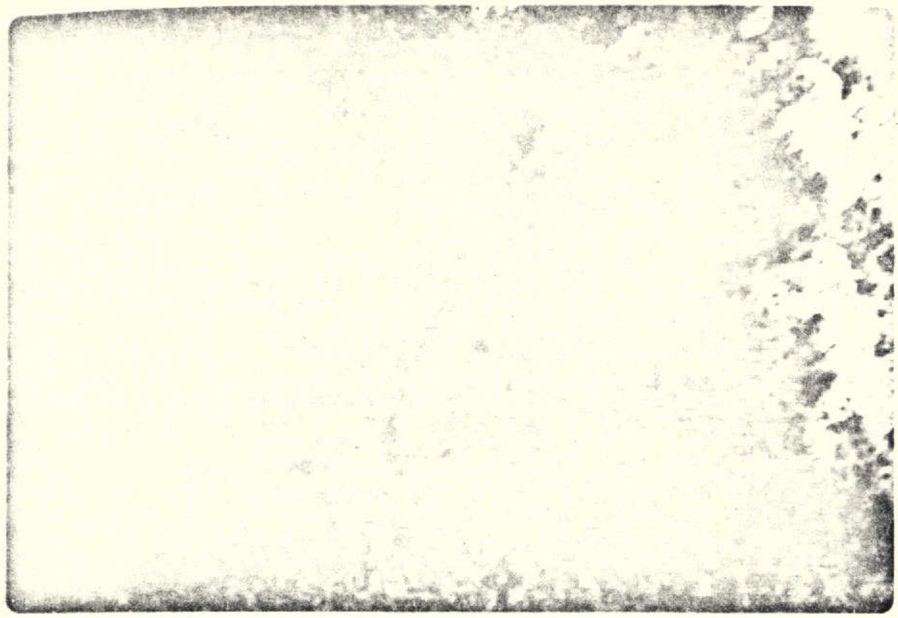


Fig. 19. A false color rendition produced on the miniadcol system utilizing temporal and multispectral ERTS-1 imagery covering the Doon, Iowa flightline. The following color filters and MSS bands were used - May 11, 1973 - MSS5 (blue) and MSS7 (red); June 16, 1973 - MSS5 (blue) and MSS7 (red). General color responses for known fields are listed in Table 9.

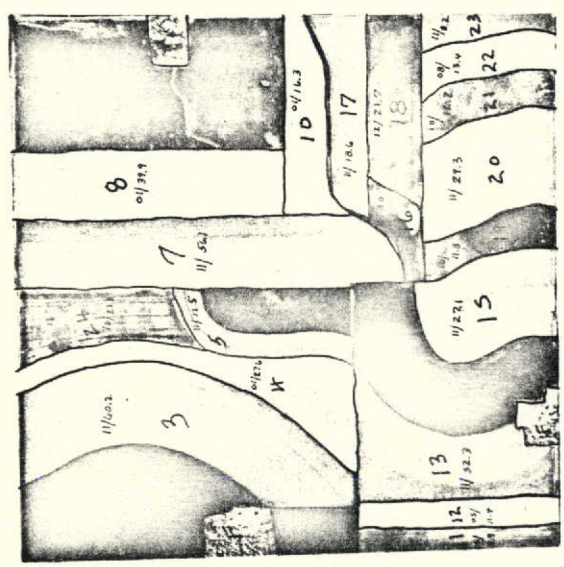


Fig. 20. Black and white print of 1 section in the O'Brien County flightline, August 10, 1973, produced from imagery exposed with a #89B filter (near infrared). Large black numbers are field identification numbers and small numbers with / are field types and acreage estimates, respectively. 12 = soybean, 11 = corn, 10 = alfalfa, 05 = pasture, 01 = oats and 08 = other stubble.

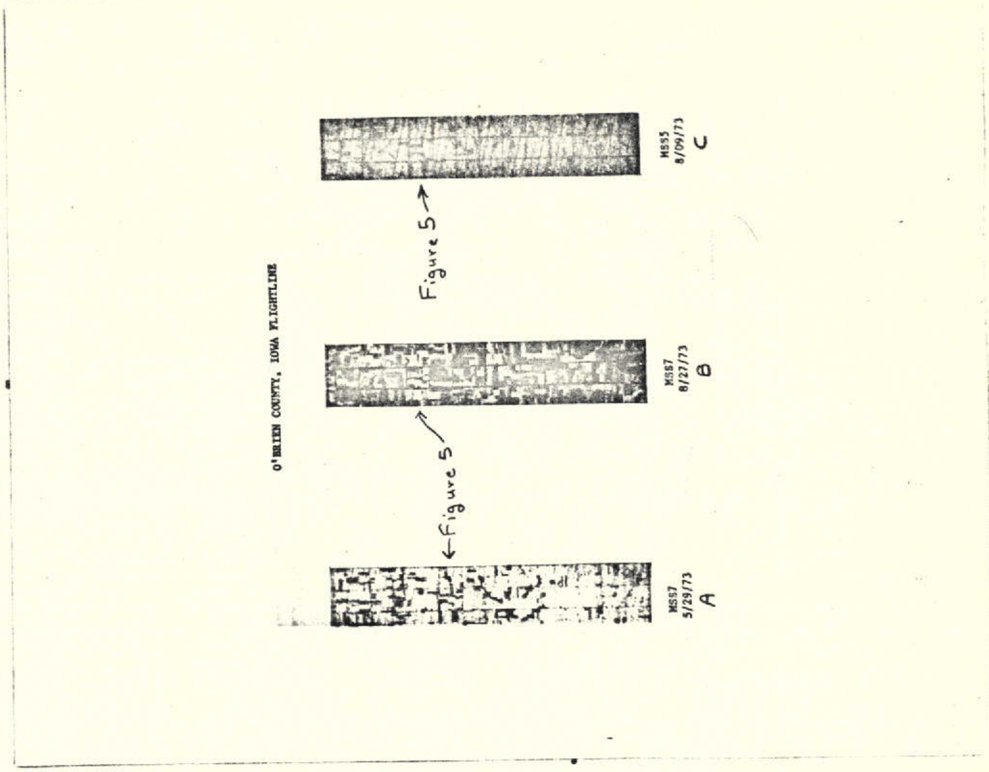


Fig. 21. Black and white print assembled from selected temporal ERTS-1 imagery covering the O'Brien County flightline during 1973. The section noted is illustrated in Fig. 20 for interested readers.

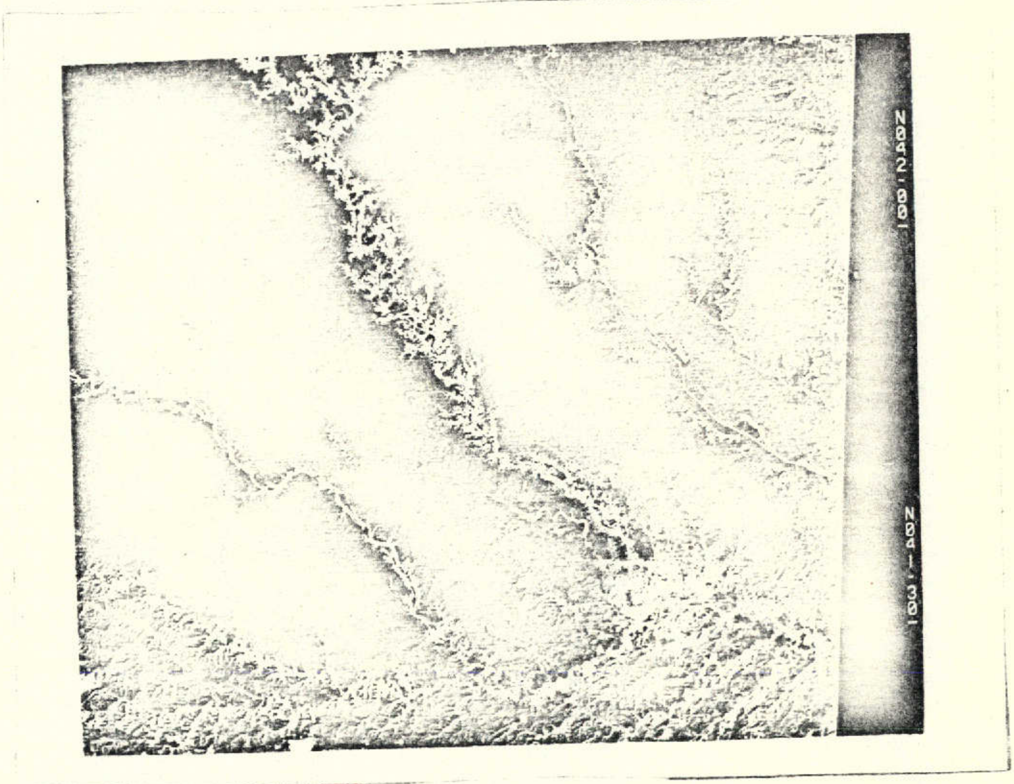


Fig. 22. Black and white enlargement of MSS7 ERTS-1 coverage of central Iowa during January of 1973. Forested land and towns are accentuated due to snow cover.

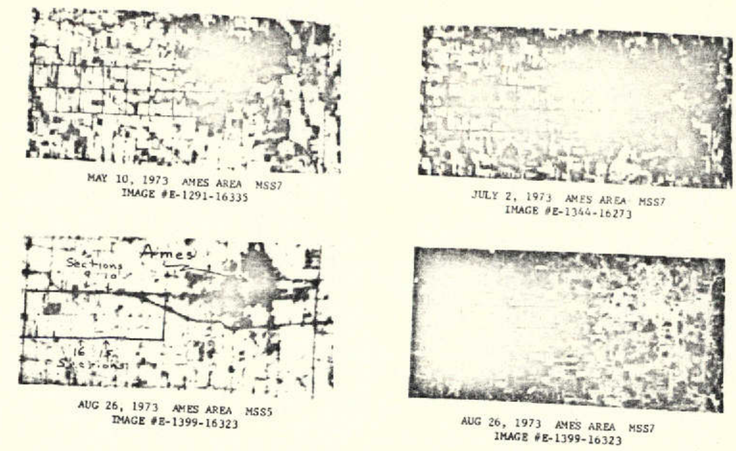


Fig. 23. Black and white print assembled from selected temporal ERTS-1 imagery covering the Ames, Iowa flightline during 1973. The four sections illustrated in Fig. 3 are noted for the convenience of interested readers. Field types present are listed in Table 11.

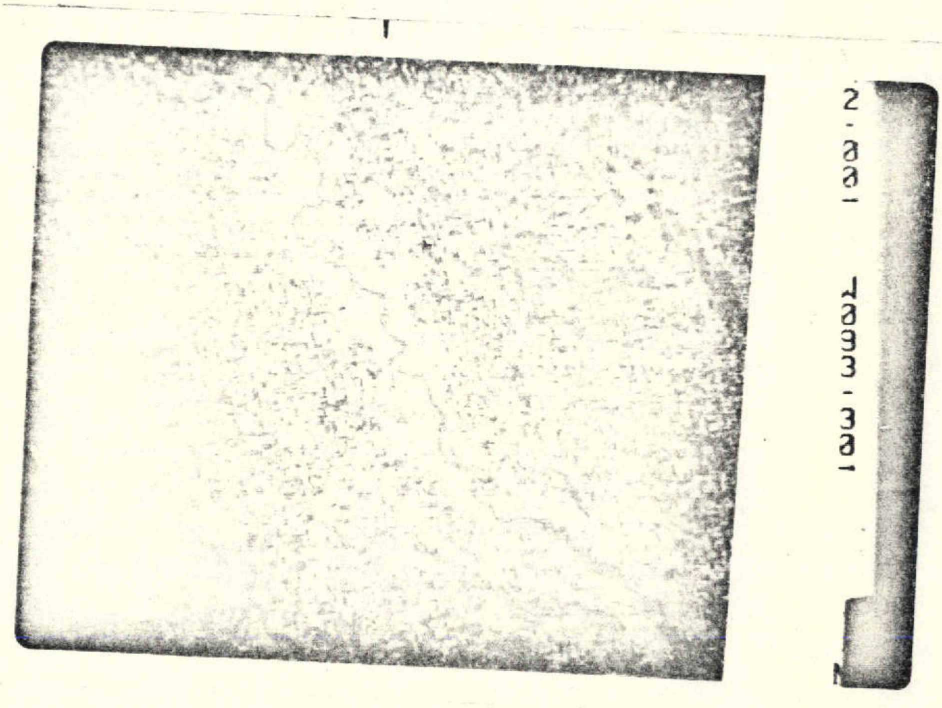


Fig. 24. A miniadcol produced color infrared rendition of ERTS-1 imagery covering the Ames, Iowa flightline on May 10, 1973. General color responses are discussed in the main text.

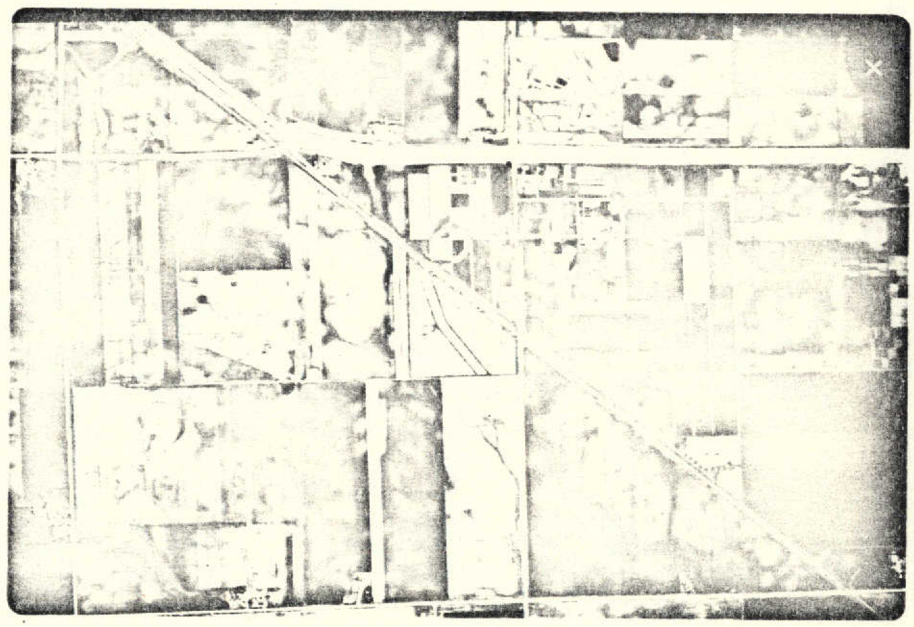


Fig. 25. A color print depicting a portion of the Ames, Iowa flightline: color infrared - May 1973.

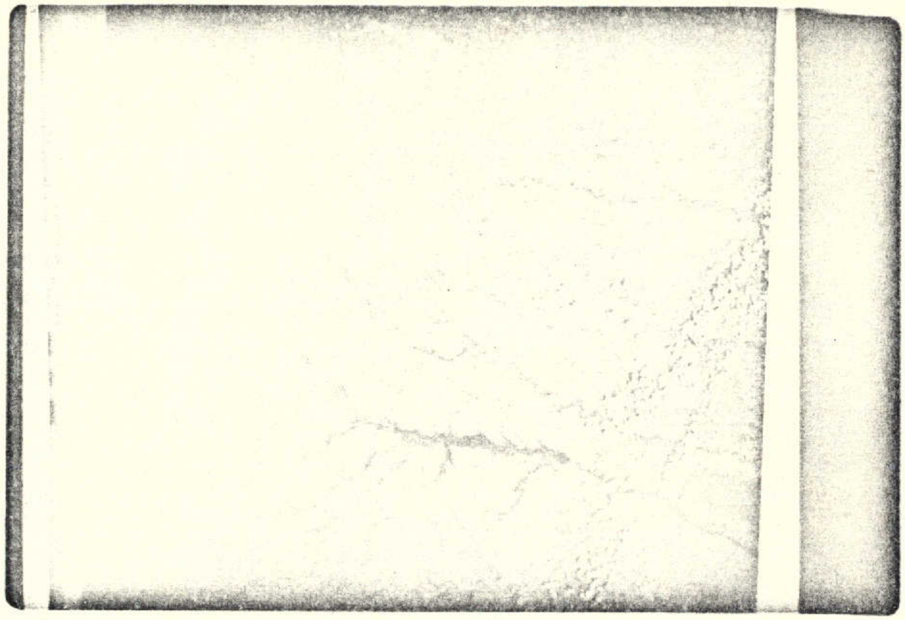


Fig. 26. A false color rendition produced on the miniadcol system utilizing selected temporal and multi-spectral ERTS-1 imagery covering the Ames, Iowa flightline. The following color filters and MSS bands were used - May 9, 1973 - MSS5 (blue) and MSS7 (green); July 2, 1973 - MSS7 (red).

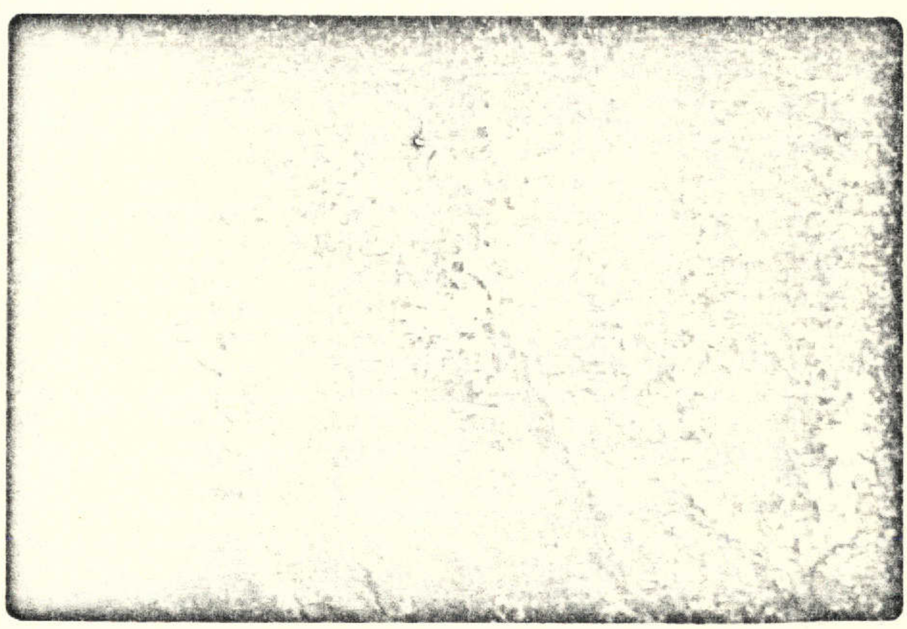


Fig. 27. A false color rendition representing a close-up of the imagery depicted in Fig. 26.

Fig. 28. Black and white enlargement of MSS7 ERTS-1 imagery covering Iowa during May and June of 1973 assembled into a state mosaic. The principal soil association areas of Iowa are superimposed and described.

Fig. 30. Black and white enlargement of MSS7 ERTS-1 imagery covering central Iowa in May of 1973 with soil association lines superimposed.

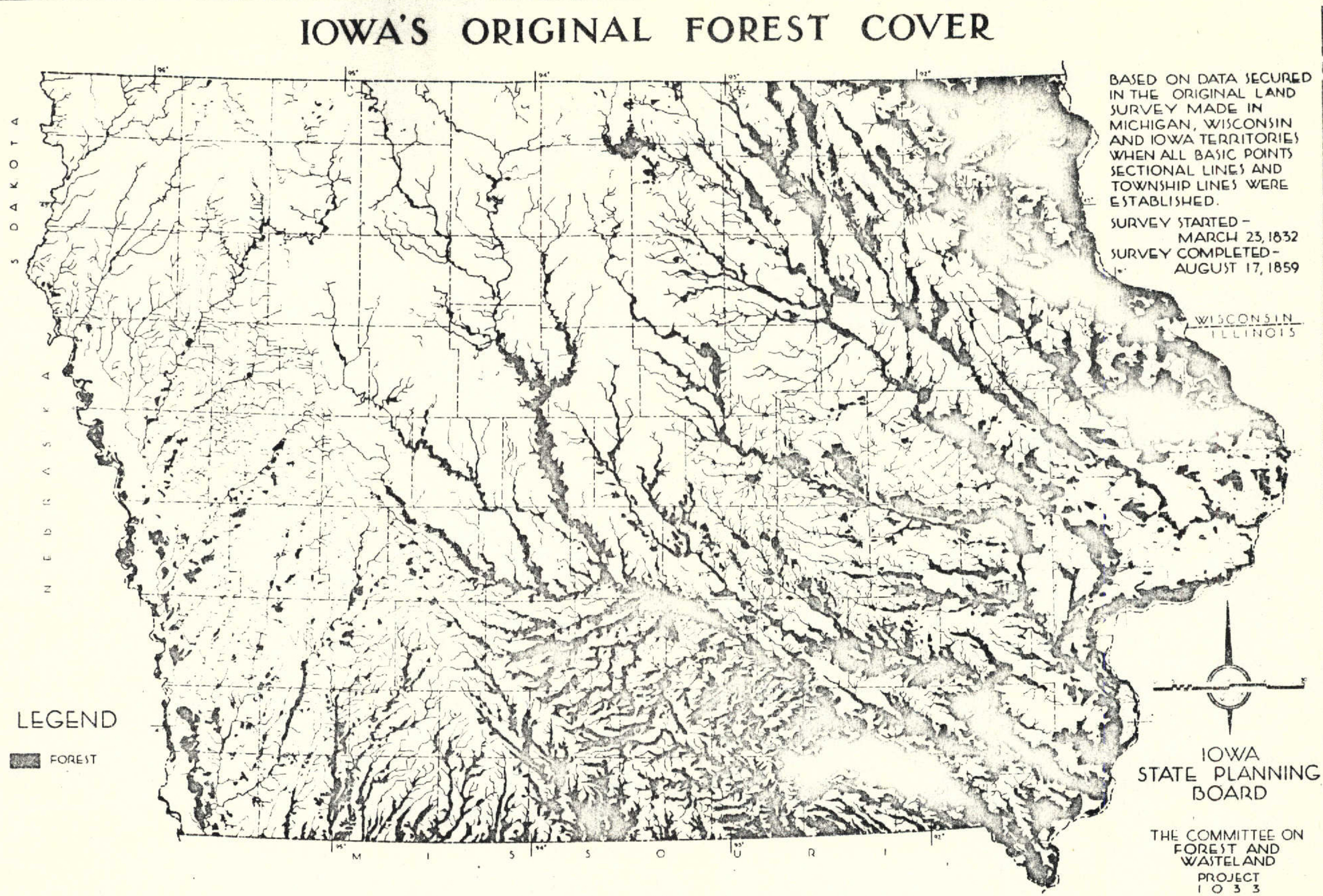


Fig. 29. Map indicating early forest cover in Iowa.