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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 - acreage estimates have not been attempted to date as digital analysis using CCT's appears most practical. This analysis procedure is just beginning. Cropland identification of temporal ERTS-1 data visually appears to separate most crop types, but the timing of satellite coverage may be critical. Examples of temporal crop response classifiers are presented. 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 soil. Major soil associations are apparent. Clouds and haze were present in some areas, but the best data available was used.

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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 noted 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 the analysis of crop types. 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 will not be stated until the analysis of the digital tapes is completed and compared to actual ground truth.

ERTS-1 imagery lacks the detailed information available from low level platforms, however, ERTS-1 provides the broad synoptic aspect of a given area and this greatly aids photo-interpretation. For example, many of the soil features present on the state mosaic discussed in this report were never before seen by people working in this area of research presented as one compact photograph.

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. 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. Temporal coverage is a powerful tool for the photo-interpretor. 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. Maximum information will probably be attained using a mixture of visual and digital products.

BODY OF REPORT

Introduction

The natural resources of Iowa are currently of concern in various state agencies in Iowa. Cropland acreage estimates, forestland inventories, the classification and inventory of soil resources and general land use are examples. In order to obtain these estimates, sampling type surveys have been previously employed in many cases. Advances in remote sensing - photo interpretation technology provide vehicles to obtain or estimate these desired parameters. This report assesses the capabilities of ERTS-1 and low-level underflight imagery of various formats to obtain these necessary 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 has been previously reported.

Results and Discussion

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

a) General statements concerning ERTS-1 coverage and usefulness (1973)

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 quite 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-interpretor. These results have been reported in detail in a previous Type II report. 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.

b) Ames test site (1973)

By using the standard catalogs provided through this NASA contract, springtime ERTS-1 imagery which was essentially cloud-free covering all of Iowa was requested and received from NASA. A state mosaic was produced from this imagery and is shown in Fig. 1. 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 are in various states of springtime tillage - light and grey. Areas of Iowa which are intensively row-cropped are quite apparent (lighter areas). Many soil features are, also, apparent and they will be discussed under the soils portion of this report. The features shown on this mosaic result mainly from the land use adapted to an area depending upon soils present and topography.

An enlargement of the test site near Ames is presented in Fig. 2 to illustrate the detail present in Fig. 1. This enlargement also illustrates one of the strong features of temporal analysis. At this time (May 10, 1973) most dark fields in Fig. 2 are pasture or alfalfa. Analysis of the 1972 imagery showed that misclassifications between these field types and corn and soybeans occurred. Springtime imagery should minimize this field spectral response problem. It also must be noted that other dark areas are present (forested areas and towns). These areas must be accounted for if digital computer analysis procedures are used. By examining other ERTS-1 imagery, we found that MSS5 in August high-lighted roads, towns and stubble fields. MSS7 at that time provides visual separation of corn and soybean fields. Therefore, by using this multispectral and temporal approach we hope to improve the cropland acreage estimates of 1972 which relied solely on single date coverage.

In the Ames area test site we have recorded a black to white visual response to known fields which were visible on the temporal ERTS-1 imagery discussed above. These results are presented in Fig. 3. This figure indicates that fields which will be corn, soybeans and oats are separated from the other two field types using MSS7 on May 10^{th}. MSS7 on August 26^{th} separates soybeans from the other field types. MSS5 on August 26^{th} separates most oats fields from the other field types. As can be seen by noting the standard deviations in this figure, all inclusive separations are not attained. Our intent, however, is to use this preliminary analysis to developd a computer crop response classifier. Then the ERTS-1 digital data corresponding to these dates and spectral bands will 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 separatable using MSS7 on either May 10^{th} or August 26^{th}. Some oats fields were, however, separatable using MSS5 on August 26^{th}. If other MSS5 bands were available shortly after oats harvest, this could be only a slight problem. 2) On May 10^{th} 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.

Digital tapes for the May 10^{th} and August 26^{th} time periods have been received. We are presently directing our attention to the development of the field response classifier using the CCT's. This will not be a simple task as we do not know at this time whether the temporal-multispectral ERTS-1 data will be superimposable. If this is, in fact, possible, we will attempt acreage estimates using this procedure and compare these with known ground truth. At that time we will be able to more fully assess the capabilities of ERTS-1 for this particular use.

c) Northwestern Iowa test site in Lyon County (1973)

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. 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.

Black and white visual analysis of MSS7 revealed that fields to be planted to corn and soybeans were separatable from oats, alfalfa and pasture using May 11th, May 30th or June 16th imagery. On June 16th imagery, however, 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. 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 gray. 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 separatable with respect to spectral responses as measured with the ERTS-1 satellite. Resolution may remain a problem with respect to acreage estimation, but this will be tested at the Ames test site with digital data.

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. An example of this product is shown in Fig. 4. The intent was to determine if various fields of interest could be separated because of the temporal variation in the multispectral response of these fields. If they were separatable 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 separatable 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. This is illustrated in Fig. 4 and summarized in Table 1. Similar false color imagery have been produced at the Ames test site.

Table 1. 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) Northwest Iowa test site in O'Brien County (1973)

August of 1972 ERTS-1 imagery covering the area immediately east of the Doon flight line appeared very sharp and detailed. For this reason the August

1973 NASA provided underflights included this area. An example of this imagery in shown in Fig. 5. (Black and white print filtered with an 89B filter is illustrated). This is an area of Iowa which is intensively row-cropped as the soils are very fetile 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-1 imagery 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. 6. 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.

Fig. 6a generally separates oats, alfalfa, pasture and towns from land which will be planted to soybeans and corn in the 1973 crop growing season. Fig. 6b generally separates soybeans and uncut alfalfa from corn, pastureland and towns. Fig. 6c provides information essential to separate towns, roads and stubble fields from corn and soyben 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. 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.

<u>Results and Discussion</u>: <u>Forestland Inventory</u> by George W. Thomson, Professor of Forestry, Iowa State University

a) Forest area determination from 70 mm ERTS-1 imagery

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

The method of evaluating the reliability of ERTS-1 imagery for the quantitative measure of forest acreage has been to transect the 70 mm film on the sliding stage of a microscope using the 4x objective. Recording of the transect distances that fall on assumed forest and calculating the percentage of total line transect that is interpreted as forest has allowed acreage estimation of forest and has permitted comparison with the results obtained by transecting ASCS black and white enlargements. All imagery obtained while the forest and pasture vegetation was in the growing period had yielded highly inaccurate results in earlier studies.

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 MSS5. The presence of snow cover aided immeasurable by screening out the low growing brushy areas and the wooded pastures that lie adjacent to the hardwood forests of Iowa. See Figure. 7.

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 2 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 gray 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 2. 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 MSS5 January 4, 1973 70 mm imagery
	- - - - Acres	- - - - - -
Pilot Mount	5517	4834
Dodge	1046	682
Yell	4833	5334
Des Moines	1718	1734
Marcy	1639	1848
Worth	5875	5265
Peoples	0	0
Douglas-Cass	4748	5690
Total	25376	25387

Results and Discussion: Soil Association Mapping by Tom E. Fenton, Associate Professor of Soils, Iowa State University

a) Soil association mapping

The state mosaic shown in Figure 1 was used as a base for soil association lines transferred from an existing map. Imagery used to construct the mosaic was MSS7, 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 period. These areas are very light colored on the imagery and are closely related to the soil association lines.

The regions of greatest contrast are between the Clarion-Nicollet-Webster soil association area and adjacent areas. The landscape of the C-N-W area is of low relief and lacks a well integrated drainage pattern. Slope gradients are generally 5 percent or less, and the soils are well suited for intensive row-crop production.

The landscape to the south of the C-N-W area is a loess-covered dissected glacial till plain. A large percentage of this area has slope gradients greater than 5 percent. These landscape characteristics result in a land-use pattern with a high percentage of pasture, hay, and timber. The MSS7 imagery shows these areas as dark gray to black.

The soil association areas of the state that have patterns interpreted to be associated with intensive row-crop production are the following: Moody, Galva-Primghar-Sac, Clarion-Nicollet-Webster, Tama-Muscatine, Dinsdale-Tama, Cresco-Lourdes-Clyde, Kenyon-Floyd-Clyde, and the Luton-Onawa-Salix area on the Missouri River floodplain.

Figure 1. ERTS-1 mosaic of Iowa using MSS7 imagery in May and June of 1973. Features are described in text.

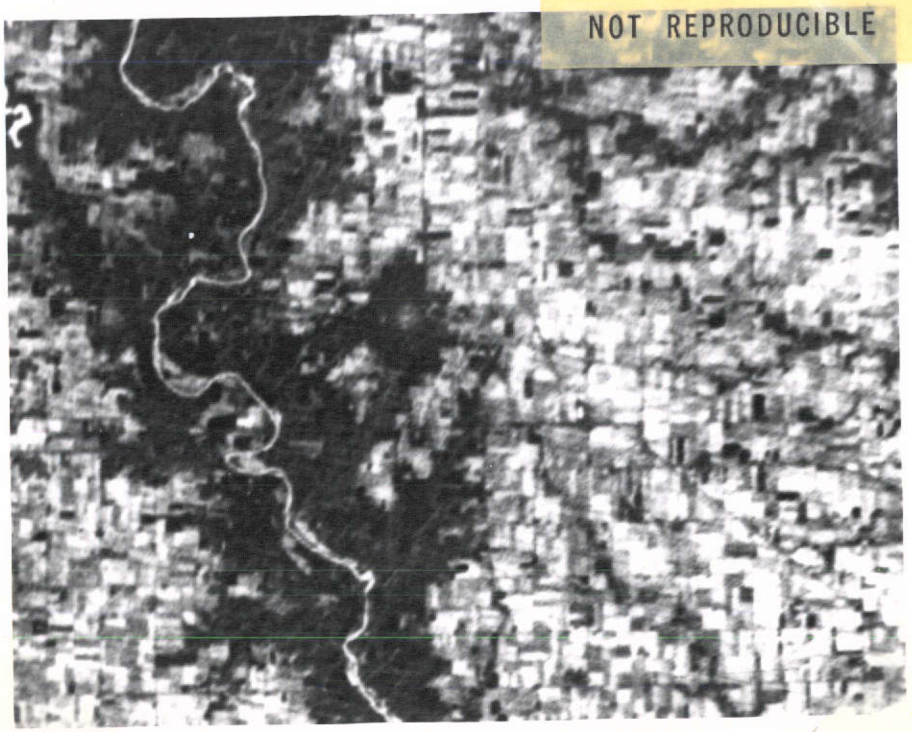

Figure 2. ERTS-1 enlargement of MSS7 imagery used to produce the state mosaic in Figure 1. This portion is located near Boone, Iowa on the Des Moines River in central Iowa.

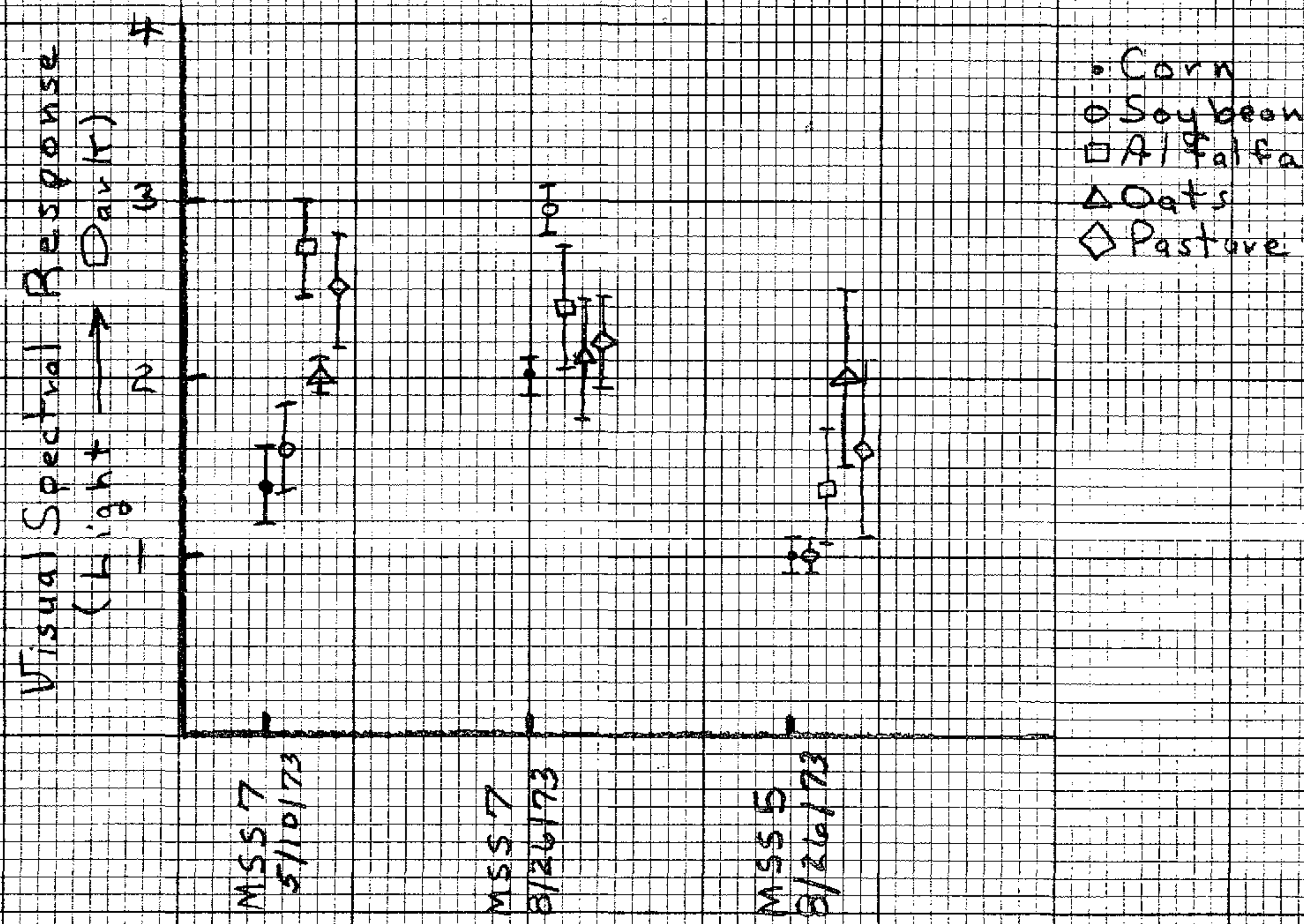

Figure 3. Temporal, multispectral black to white visual response (means and 1 standard deviation) as perceived on ERTS-1 black and white enlargements of various field types in the Ames flightline during 1973.

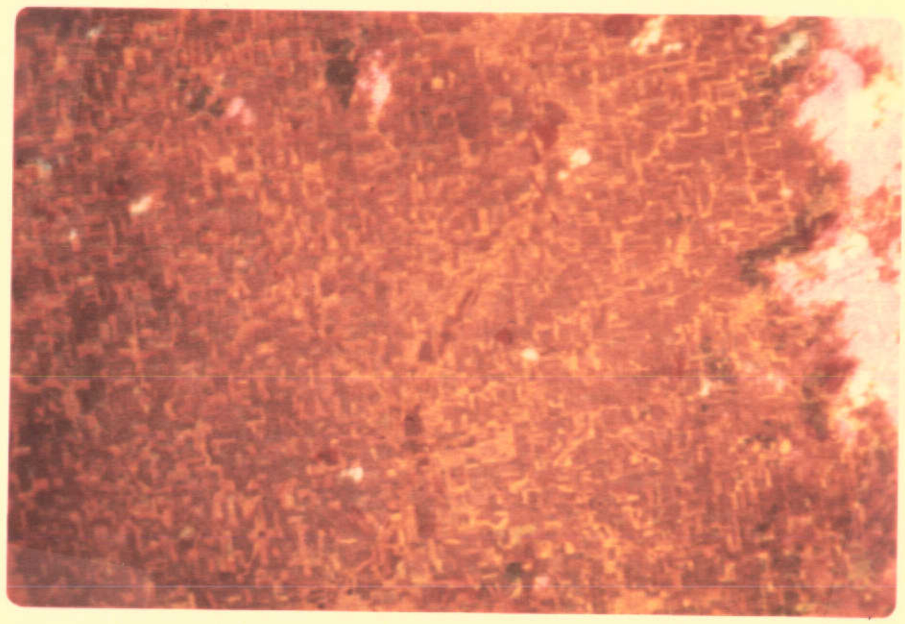

Figure 4. Color print of temporal and multispectral ERTS-1 imagery produced on the Miniadcol system. Color responses of known fields of the Doon flightline are given in Table 1. Also, the ERTS-1 imagery date and MSS band used are presented there.

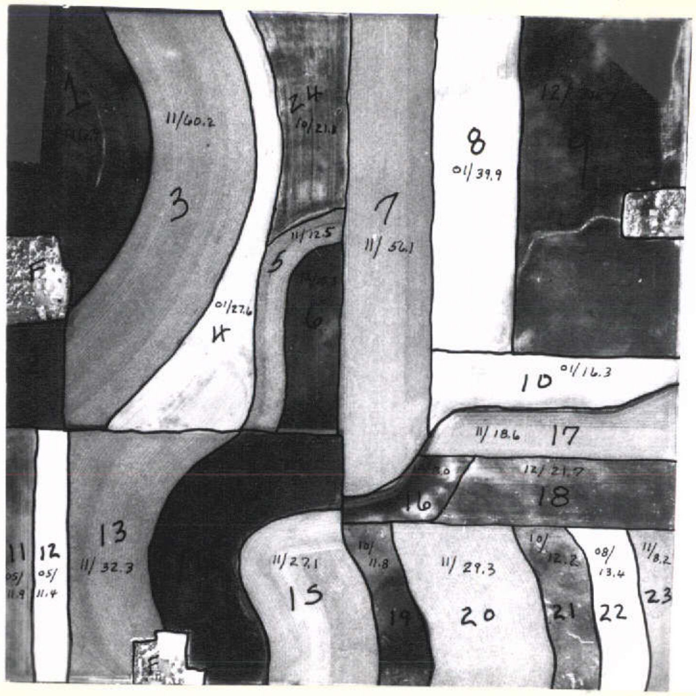

Figure 5. Black and white print of 1 section in the O'Brien county flightline, August 10, 1973, produced from imagery exposed with a #89B filter (near infrared). Large black numbers are field identification numbers and small numbers with / are field type and acreage estimate, respectively. 12 = soybean, 11 = corn, 10 = alfalfa, 05 = pasture, 01 = oats and 08 = other stubble.

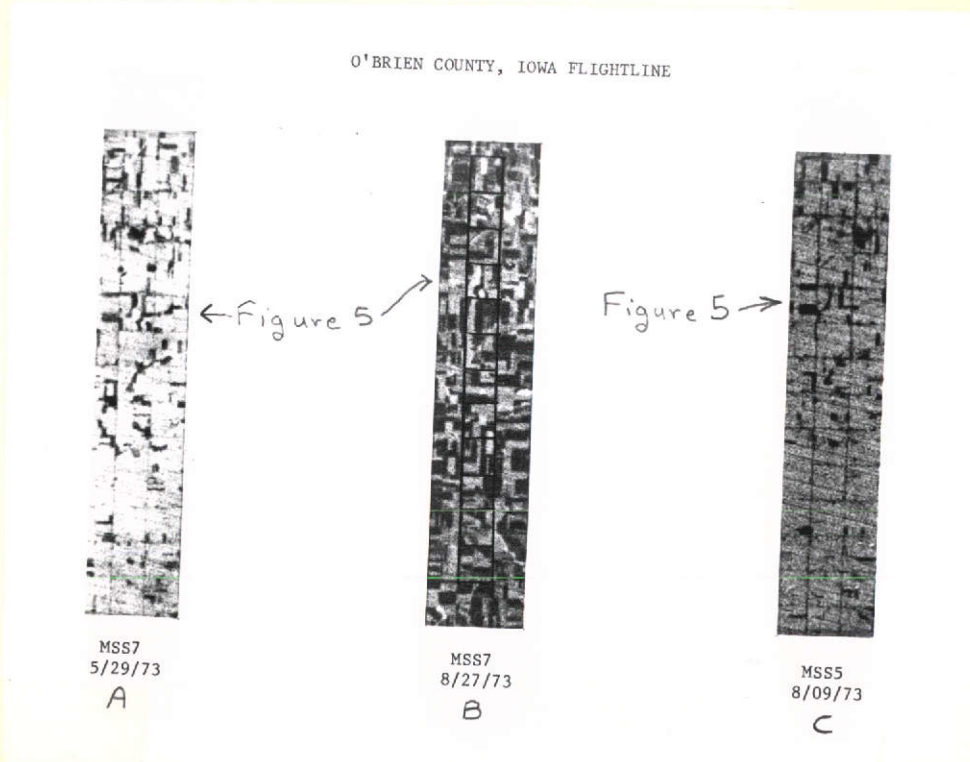

Figure 6. A black and white print of temporal, multispectral ERTS-1 imagery of the O'Brien County, Iowa flightline during 1973. The section illustrated in Figure 5 is noted for interested readers.

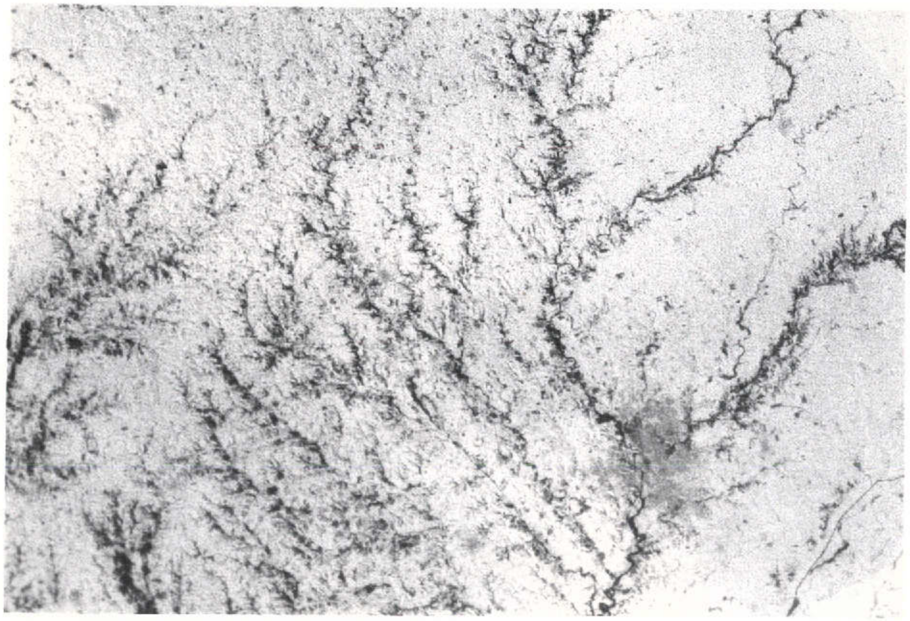

Figure 7. A black and white print of wintertime ERTS-1 imagery (January 73) in central Iowa. MSS5 is illustrated.

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Significant Results

Iowa State Mosaic Using Springtime ERTS-1 Imagery

Springtime ERTS-1 imagery covering pre-selected test sites in Iowa showed considerable detail with respect to broad soil and land use patterns. Other cloud-free imagery covering the majority of Iowa was ordered and this imagery has been incorporated into a state mosaic.

The state mosaic was used as a base for soil association lines transferred from an existing map. Imagery used to construct the mosaic was MSS7, 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 period. These areas are very light colored on the imagery and are closely related to the soil association lines.

The regions of greatest contrast are between the Clarion-Nicollet-Webster soil association area and adjacent areas. The landscape of the C-N-W area is of low relief and lacks a well integrated drainage pattern. Slope gradients are generally 5 percent or less, and the soils are well suited for intensive row-crop production.

The landscape to the south of the C-N-W area is a loess-covered dissected glacial till plain. A large percentage of this area has slope gradients greater than 5 percent. These landscape characteristics result in a land-use pattern with a high percentage of pasture, hay, and timber. The MSS7 imagery shows these areas as dark gray to black.

The soil association areas of the state that have patterns interpreted to be associated with intensive row-crop production are the following: Moody, Galva-Primghar-Sac, Clarion-Nicollet-Webster, Tama-Muscatine, Dinsdale-Tama, Cresco-Lourdes, Clyde, Kenyon-Floyd-Clyde, and the Luton-Onawa-Salix area on the Missouri River floodplain.

NASA Contract #NAS5-21839

Significant Results

Cropland and Forestland Inventory and Identification

Forestland estimates have been attained for an area in central Iowa using wintertime ERTS-1 imagery. Earlier estimates were obtained using September and May imagery, however, the January imagery appears to provide the most information and lessens mis-interpretations caused by other vegetation types having a similar spectral response. This imagery (January, 1973) was snow-covered so that sharp forestland boundaries were apparent. A sampling type transect method was used, but the results indicate that automatic inventory estimates may be readily obtained using CCT's and the computer.

Visual analysis of multi-spectral, temporal ERTS-1 imagery indicates that temporal analysis for cropland identification and acreage analyses procedures may be a very useful tool. Combinations of wintertime (January-MSS7), springtime (May-MSS7), summertime (August-MSS7) and summertime (August-MSS6) ERTS-1 imagery separate most vegetation types. Timing can be critical depending upon crop development and harvesting times because of the dynamic nature of agricultural production. 70 mm transparencies of ERTS-1 imagery from different cycles have been successfully subjected to Miniadcol color additive analysis procedures yielding various vegetation type color separations. Color separations would indicate that similar separations are attainable using CCT's.