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THE ERTS-1 INVESTIGATION (ER-600)

VOLUME I — ERTS-1 AGRICULTURAL ANALYSIS

(REPORT FOR PERIOD JULY 1972 - JUNE 1973)

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS 77058

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16. Abstract

The Agriculture Analysis Team of the Johnson Space Center conducted a 1-year-long investigation of ERTS-1 multispectral data to evaluate how well features of agricultural importance could be detected, identified, and located; and their areal extent measured. Six study areas were selected in cooperation with the U.S. Department of Agriculture. Two basic analytical approaches were used to meet the objectives. The conventional image interpretation technique revealed that a particular color was an indication of the density of vegetative cover, not an indication of crop classification. Computer-aided techniques were used to classify crop types (i.e., small grains, truck farm crops, grasses, summer fallow) to accuracies as high as 95 percent on large (12 hectares or more) well-defined fields. A further breakdown into crop species (wheat, barley, soybeans, oats, corn) reduced the accuracy to 70 to 80 percent for single-date observations.

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VOLUME I — ERTS-1 AGRICULTURAL ANALYSIS

(REPORT FOR PERIOD JULY 1972 - JUNE 1973)

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PREFACE

This report is one of seven separate reports prepared by six discipline-oriented analysis teams of the Earth Observations Division at the NASA Lyndon B. Johnson Space Center, Houston, Texas.

The seven reports were prepared originally for Goddard Space Flight Center in compliance with requirements for the Earth Resources Technology Satellite (ERTS-1) Investigation (ER-600). The project was approved and funded by NASA Headquarters in July 1972.

This report (Volume I) was accomplished by the Agriculture Analysis Team. The following is a list of the team members.

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The total investigation is documented in the following reports.

Volume	Title	NASA Number
	A COMPENDIUM OF ANALYSIS RESULTS OF THE UTILITY OF ERTS-1 DATA FOR LAND RESOURCES MANAGEMENT	TM X-58156 JSC-08455
I	ERTS-1 AGRICULTURAL ANALYSIS	TM X-58117 JSC-08456
II	ERTS-1 COASTAL/ESTUARINE ANALYSIS	TM X-58118 JSC-08457
III	ERTS-1 FOREST ANALYSIS	TM X-58119 JSC-08458
IV	ERTS-1 RANGE ANALYSIS	TM X-58120 JSC-08459
V	ERTS-1 URBAN LAND USE ANALYSIS	TM X-58121 JSC-08460
VI	ERTS-1 SIGNATURE EXTENSION ANALYSIS	TM X-58122 JSC-08461
VII	ERTS-1 LAND USE ANALYSIS OF THE HOUSTON AREA TEST SITE	TM X-58124 JSC-08463

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1.0 SUMMARY

The general objective, in cooperation with the U.S. Department of Agriculture (USDA) Agricultural Stabilization and Conservation Service (ASCS), was to evaluate how well features of agricultural importance could be detected, identified, and located; and their areal extent measured using ERTS-1 data.

The ERTS-1 multispectral scanner (MSS) data for each of six agriculture study areas were analyzed for the 1972 crop year. From a set of 18 counties under study by the ASCS, six study areas of 3.2 by 9.6 kilometers (2 by 6 mi.) were selected for intensive ground-truth collection and study. The study sites were Hill County, Montana; Imperial County, California; Hardin County, Iowa; Holt County, Nebraska; Butte County, California; and Worth County, Georgia. These were selected to provide a manageable study area while retaining a variety of crop types, geographical conditions, and varying levels of complexity for testing, training, and evaluation.

1.1 ANALYSIS

The data were analyzed using automatic data processing (ADP) and conventional image interpretation techniques. The ADP approach used data screening and clustering programs at the NASA Lyndon B. Johnson Space Center (JSC) for the selection of homogeneous training and test fields and the programs for supervised classification, designated LARSYS, developed by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University.

The conventional image interpretation consisted of image enhancement and photointerpretation. Image enhancement utilized black-and-white 24-centimeter (9-1/2-in.) imagery received from the Goddard Space Flight Center (GSFC) which was processed on the additive color viewer/printer (ACVP) and the multiband camera film viewer (MCFV). Enhanced images were also made from displays of digital data on the data analysis station (DAS). These products and enlarged segments of color products provided by the GSFC were then analyzed by conventional image interpretation.

The results of the investigation showed that ERTS-1 data generally could be used for crop classification, location, and area measurement. Area measurements were made of representative fields in the study areas using a mechanical/electronic planimeter to manually trace the field borders. Additive color-enhanced ERTS-1 imagery of about 1:130,000 scale was used as base photography for the measurements. Ground-truth data were used for precise instrument calibration.

Boundary detection was found to be the key to field detection and measurement. Field width, relative contrast, and orientation were very important in accurately detecting the boundaries of individual fields. In Hill County, dimensions greater than 220 meters (722 ft) under optimum conditions of contrast and orientation were necessary for clear definition.

Fields were located using a Universal Transverse Mercator (UTM) coordinate system with 1000-meter grid increments. The grid was prepared for enhanced ERTS-1 imagery of about 1:130,000 scale. The grids were constructed with a programed XY-plotter which was set accurately to scale by comparing measured distances between specific features on the imagery to U.S. Geological Survey (USGS) topographic maps. The appropriate grid was matched to the control points by locating tracts in the 19-square-kilometer (12-sq. mi.) study areas to within approximately 200 meters (656 ft).

1.1.1 Conventional Image Interpretation

Conventional interpretation of the enhanced imagery revealed that the relative contrast of adjacent features and their geographical orientation were important in ascertaining their detectability. Linear features, such as the long narrow fields in Hill County, were more difficult to detect when parallel to the scan lines on an MSS image than when normal to the scan direction. The data were acquired in Hill County (August 7, 1972) late in the growing season and most of the fields had been harvested, which left little contrast between the cropped and fallow fields. Fields 90 meters (300 ft) wide oriented north-south were detectable. The narrowest field detected with an east-west orientation was 135 meters (450 ft) wide.

The Imperial County test site crops, which had similar spectral reflectance characteristics, were grouped into classes on the ACVP false-color infrared (IR) enhancement. The smallest field easily identifiable was 6.5 hectares (16 acres), rectangular, bright, and bordered by contrasting fields. A dividing border, such as a dirt road about 40 meters (131 ft) wide, was required to detect the boundary between fields of the same contrast. Conventional interpretation beyond Level II (crop vs. noncropland) was almost impossible.

Relating a particular color to just one crop species was attempted using various training fields, and these results also quickly indicated that crop classification in this manner was almost totally ambiguous. The colors were found to be an indicator of the density of vegetative cover.

The crops in Hardin County were identified in those fields which could be detected. Corn, soybeans, and oats were identified with 85- to 95-percent accuracy on the basis of color.

1.1.2 Computer-Aided Classification

Atmospheric correction techniques were not used in the computer-aided analysis because of the lack of ground data. Photometers which would have measured the atmospheric effect of the solar energy reaching the Earth were not available for the test sites during the ERTS-1 overpasses.

Computer-aided classification of the ERTS-1 data was demonstrated to be very successful for many important crops. Clustering maps and Earth Resources Interactive Processing System (ERIPS) displays with baseline photography and/or maps were the best tools for selecting training and test fields. Crop identification was accomplished to Levels III and IV in five of the test sites. Fields smaller than 12 hectares (30 acres) were not easily identifiable. Worth County, Georgia, had many such small fields and the classification results were very poor. The long narrow fields of Hill County had rather poor results from the test fields (less than 70 percent). The smaller fields of Imperial

County had an overall test performance average of 78.7 percent. Hardin County, which had larger fields but rather poorly defined boundaries, had a test field accuracy of 79 percent. Butte County, California, which had a variety of shapes and sizes, had an overall test field accuracy of 60.4 percent. Holt County, with large well-defined fields, had a test field accuracy of 98 percent.

1.2 CONCLUSION

Generally, only the large well-defined fields (12 hectares or more) should be considered for Level III and IV classification with the existing programs. However, for such fields, detailed land use classifications of a wide variety of agricultural features could be obtained with reliable, repeatable accuracy.

2.0 INTRODUCTION

2.1 PURPOSE

This document describes the results of an analysis conducted to determine whether ERTS-1 data could be used to meet USDA-ASCS requirements for crop identification, area measurement, and correlation of specific tracts. The evaluation was a joint effort of the National Aeronautics and Space Administration (NASA) at the JSC and of the ASCS.

2.2 BACKGROUND

In order to evaluate the utility of ERTS data for the ASCS programs, the ASCS established a test program in 18 counties representing 15 states. The Executive Director of each county received the ERTS-1 imagery of his county as a supplement to conventional aircraft coverage. These data were used by ASCS personnel to update base photo coverage and to perform a limited analysis.

In the spring of 1972, a cooperative agreement was made between ASCS and NASA-JSC to evaluate ERTS-1 data in detail for applications in agriculture. Six of the 18 ASCS study sites were selected for intensive study at JSC. Areas of either 63 square kilometers (39 sq. mi.) or 124 square kilometers (77 sq. mi.) were identified in each county. A smaller 19-square-kilometer (12-sq.-mi.) tract within each study area was designated for intensive ground-truth collection and study and served as testing, training, and evaluation locations for the investigation.

2.3 OBJECTIVES

The first general objective of the Agricultural Investigation was to work jointly with the ASCS to evaluate how well features of agricultural importance could be detected, identified, and located; and their areal extent measured using ERTS-1 data. This general objective included the following specific objectives, which are listed in their order of priority.

1. Separate agricultural areas from nonagricultural areas.

2. Separate cropland from noncropland within the agricultural areas.

3. Determine if the existence of different crop types (e.g., row crops, small grains) could be detected within the cropland.

4. Determine if the existence of different crop species (e.g., wheat, barley, and oats) could be detected within the cropland.

5. For each major crop, determine the size of the smallest field that could be detected, identified, located, and measured.

6. Determine the effect of varying field shapes and field sizes on the accuracy of crop classification and field measurement.

7. Determine the effect of the relative contrast of adjacent fields on boundary detection and crop classification.

Figure 2-1 shows the general information hierarchy that was altered from the USGS Circular 671 land use hierarchy.

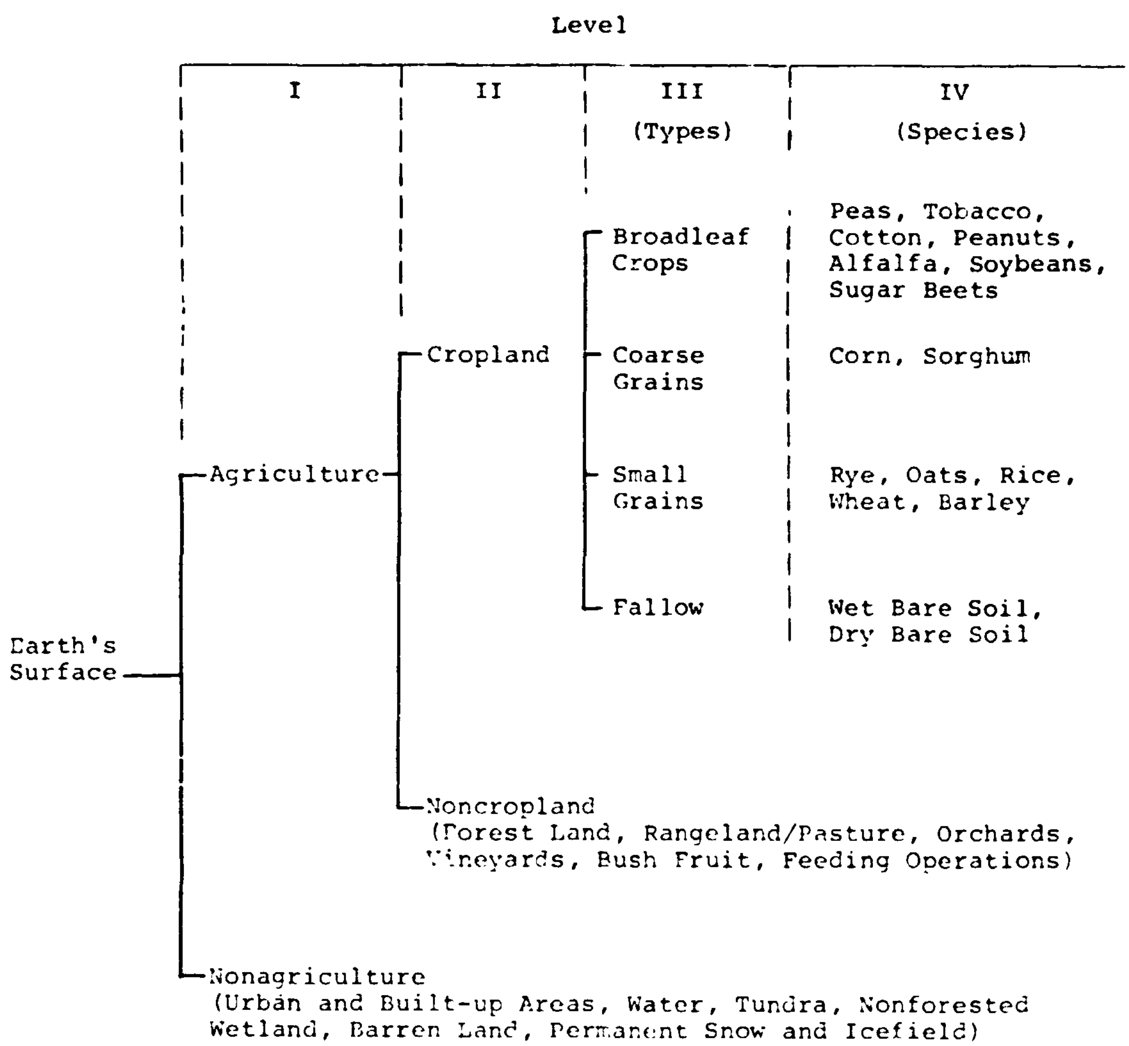

Figure 2-1.- Classification hierarchy.

Due to the peculiarities of data sets from agricultural study areas, land use classifications varied from the classification hierarchy as depicted in figure 2-1.

The second general objective was to evaluate the effect of atmospheric correction techniques on the analysis of ERTS-1 data as applicable to agriculture.

The third general objective was to become familiar with and qualitatively appraise the JSC hardware, software, and procedures to process and analyze ERTS-1 data as applicable to agricultural features.

Appendix A contains a glossary of terms, abbreviations, acronyms, and computer programs. A discussion of equipment used is given in appendix B, and appendix C contains data summary tables.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Systême International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

3.0 APPROACH

The approach of the ERTS-1 Agricultural Investigation consisted of a complete data analysis of the best data set available from the 1972 crop year for each of six 3.2- by 9.6-kilometer (2- by 6-mi.) study areas. The analysis included conventional image interpretation and computer-aided techniques. In addition, two study areas were selected for temporal analysis of 1972 crop year data.

The Sun-synchronous, near-polar orbit of ERTS-1 was designed so that virtually the entire Earth's surface was covered every 18 days. Varying degrees of sidelap prevail at different latitudes. The location and limited size of the agricultural test sites permitted complete coverage twice every 18 days by locating test sites in the overlap region. Appendix C provides a schedule of data collection passes for the first year of ERTS-1. The data were collected over each test site on two consecutive days.

Few problems were encountered concerning the receipt of ordered data. The amount of data provided on the standing order was not sufficient to meet the requirements of the investigation; however, the part of the standing order that was allowed was usually filled completely and satisfactorily. Retrospective orders were necessary to supplement the standing order.

The primary data formats used in the analysis were system-corrected (bulk) 24-centimeter (9-1/2-in.) black-and-white transparencies, 24-centimeter (9-1/2-in.) color composite transparencies (MSS bands 4, 5, and 7), and nine-track computer-compatible tapes (CCT).

A limiting factor in the analysis was the delayed receipt of data. The delay in receipt of the black-and-white imagery and the CCT's decreased the time available for analysis. Also, part of the investigation was to analyze GSFC-generated color composites, but the imagery was not available in time. Table C-II in appendix C gives an indication of the time lapse between an order and receipt for each type of data.

Because the test sites were so small (19 sq. km), the standing order included all data sets that were less than 80-percent cloud covered. Table C-IX in appendix C summarizes the percentage of data that was usable for the analysis.

3.1 STUDY AREAS AND SELECTION RATIONALE

The six study areas shown in figure 3-1 were selected because of the variety of crop types, farming practices, and geographical conditions. Study area size limitations were established by considering the volume of ground-truth data required and the size that would be manageable for analysis. Areas of either 63 square kilometers (38.6 sq. mi.) or 124 square kilometers (77.2 sq. mi.) were identified in each of the selected counties, with a smaller 19-square-kilometer (12-sq.-mi.) tract within the study area selected for intensive ground-truth collection and study. These 19-square-kilometer study areas served as testing, training, and evaluation locations to complete the objectives of the investigation.

3.1.1 Hill County, Montana

Hill County, Montana, is adjacent to the Canadian border in the gently rolling, glacial drift plain of north-central

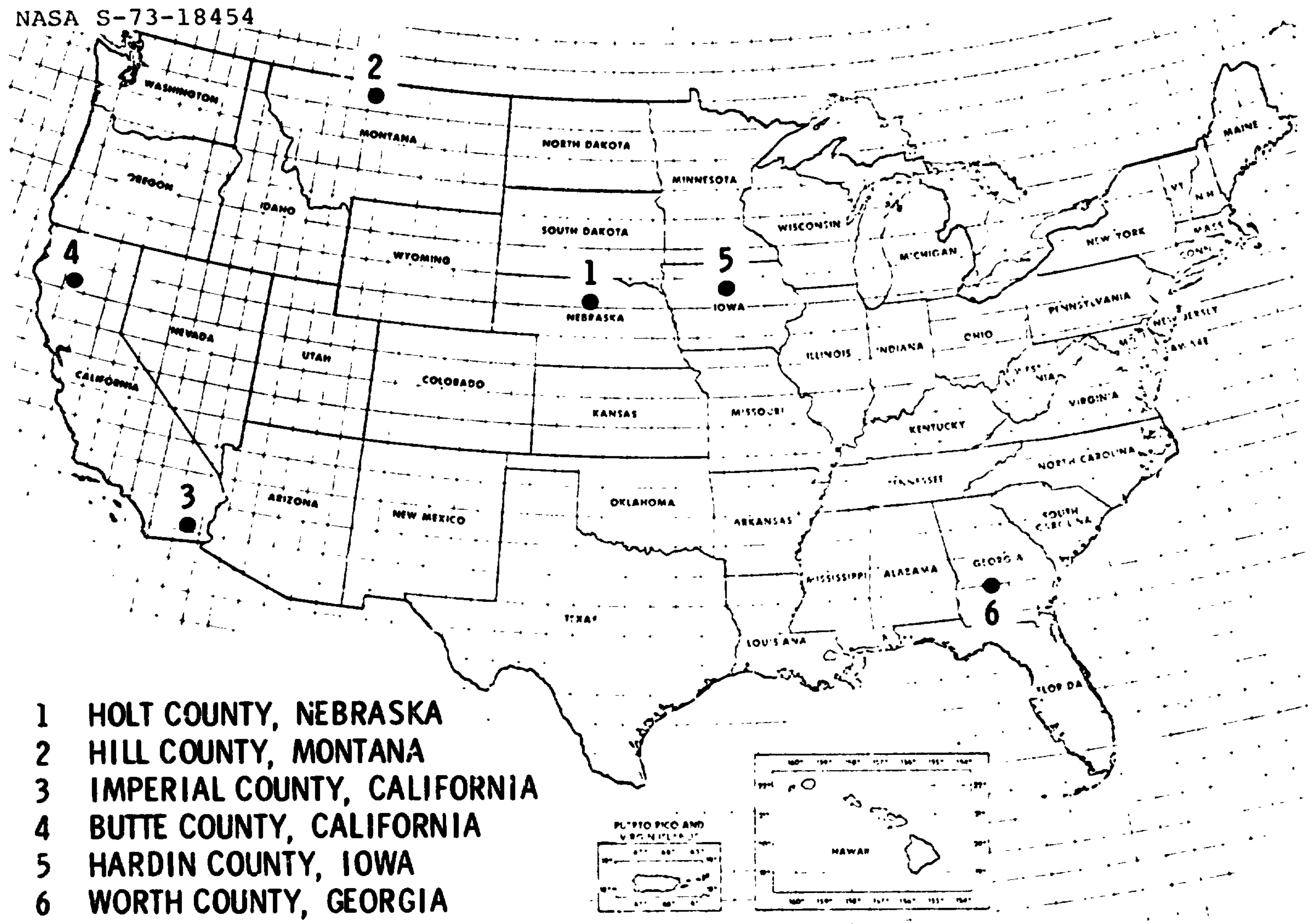

Figure 3-1.- Six agricultural study areas within the United States.

Montana. Hill County covers an area of 4708 square kilometers (2926 sq. mi.), of which 728 445 hectares (1 800 000 acres), or 96 percent, is farmland. The average farm size of this area is approximately 972 hectares (2400 acres). The strip-fallow techniques of farming practiced in this area provide narrow 91- to 107-meter (300- to 350-ft) linear fields, which approach the theoretical maximum achievable ERTS-1 resolution. The center point of the study area is located 24 kilometers (15 mi.) northwest of Havre, Montana, at latitude 48°24' N., longitude 109°53' W.

Wheat is the major crop in the area, but barley, other small grains, and alfalfa hay are also grown, with some tame pasture present. The Hill County crop calendar (fig. 3-2) shows the major crops and their growth stages. A crop calendar depicts the major crops for a particular study area and indicates the expected crop condition and maturity stage (e.g., seedbed, harvest) for the calendar year. Crop calendars are based on an average of past years' data and must be adjusted to account for any abnormalities of the growing season for that particular test area (e.g., drought, cold weather).

Hill County, Montana, was selected for study because of the unique field patterns which made it a good target for qualitative evaluation of the ERTS-1 system. These field patterns are caused by the practice of "strip-fallow" farming, in which alternate fields are left fallow. The result is a series of long narrow rectangular fields which differ considerably in their spectral reflectance characteristics.

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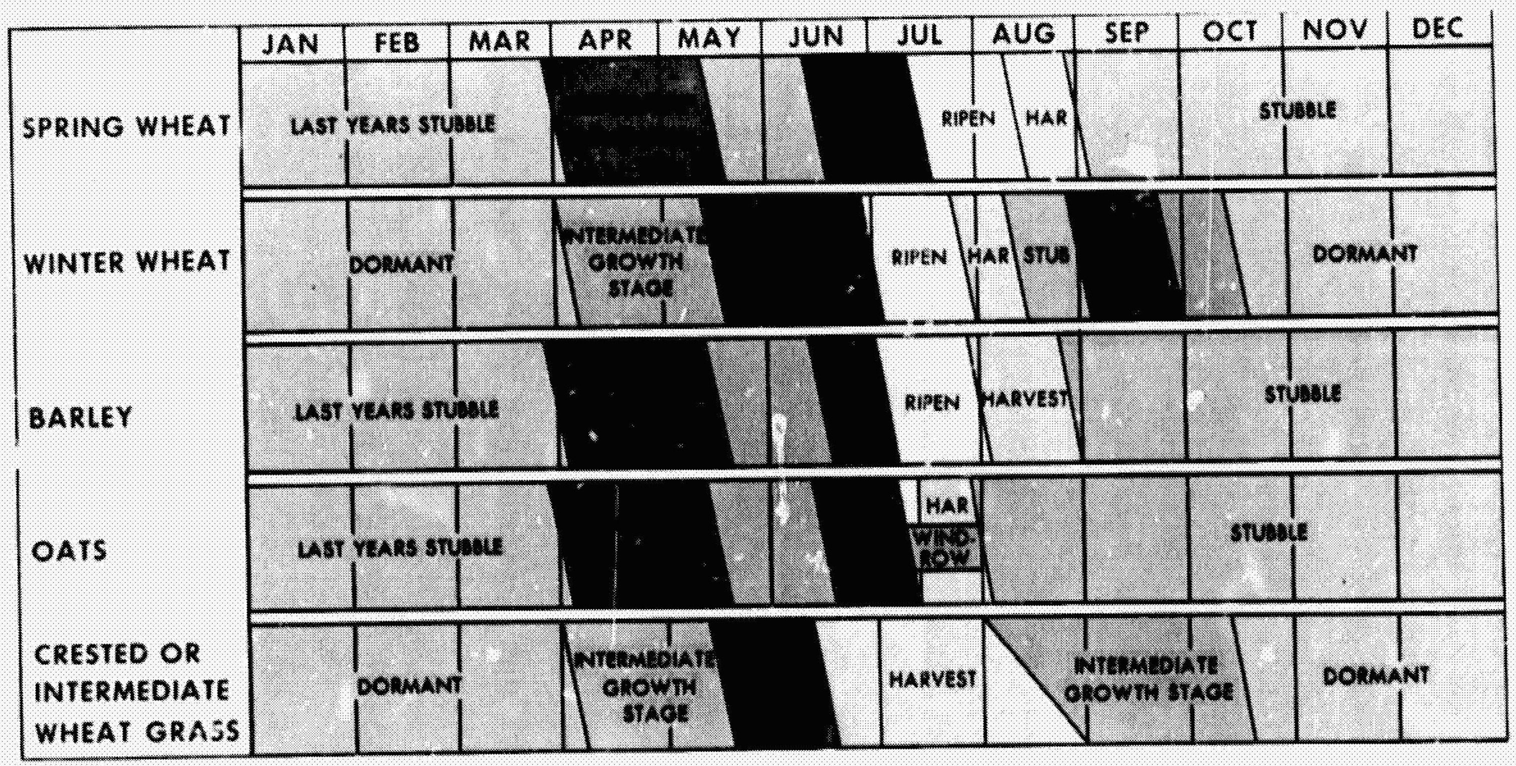

Figure 3-2.- Hill County, Montana, crop calendar.

The data on the August 7, 1972, pass (scene 1015-17392) was selected for Hill County because it was the earliest available pass. Most of the small grains had been harvested before the earliest pass over the area.

3.1.2 Imperial County, California

Imperial County, California, is located in the southeast corner of the State of California and is bounded to the south by Mexico and to the east by Arizona. Within its boundaries are the Imperial Valley and most of the Salton Sea. Imperial County is fairly large, covering 6893 square kilometers (4284 sq. mi.). However, agriculture is limited to the irrigated valley, which is approximately 242 915 hectares (600 000 acres), or one-fifth of the county. The average farm size in the valley is 253 hectares (625 acres). The center of the study area is 11 kilometers (7 mi.) southeast of El Centro, California, at latitude 32°53' N., longitude 115°28' W.

Agriculture is dependent upon irrigation from the Colorado River, and nonirrigated land is desert vegetation (mesquite, yucca, cacti) of little economic value. A large variety of crops are grown in the irrigated valley (e.g., alfalfa hay, barley, sugar beets, cotton, vegetables, and grain sorghum). The climate permits winter and summer crops. Figure 3-3 is a crop calendar for Imperial County.

Imperial County was selected for study primarily because it was one of the few areas in the 18 test counties in which a variety of crops were growing during the entire data collection period (August to December 1972). The area's

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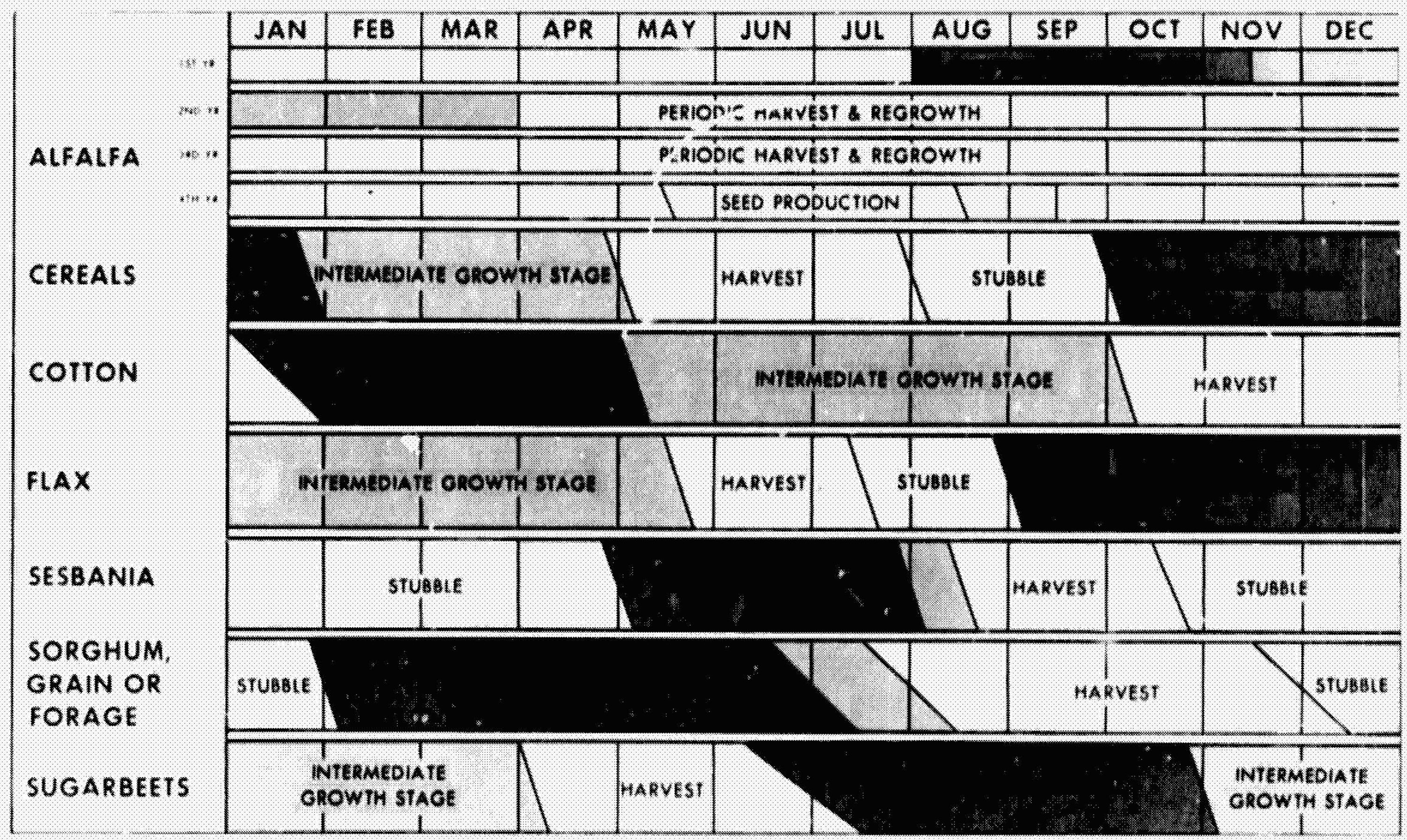

Figure 3-3.- Imperial County, California, crop calendar.

year-long growing season insured a variety of crops in various stages of maturity. Most of the fields were well defined because they were bounded by roads or irrigation canals, and thus were well suited for this investigation. Many of the winter crops of Imperial County were in an early growing stage when ERTS-1 was launched late in the 1972 summer growing season. Data sets from the November 6, 1972, pass (scene 1106-17504), were selected for analysis.

3.1.3 Hardin County, Iowa

Hardin County, Iowa, is located in the north-central region of the state and is bisected by the Iowa River. The area is located in the heart of the fertile, gently rolling, north-central glacial till plain. The county covers an area of 924 square kilometers (574 sq. mi.), of which approximately 141 700 hectares (350 000 acres), or 95 percent of the area, is farmland, with about 75 percent cultivated cropland. The average farm size is 88 hectares (217 acres); and corn, soybeans, oats, and other feed grains are the most extensively grown crops. Some of the cropland is in hay, and a small portion of the land is permanent pasture of tame and native grasses. Figure 3-4 is a crop calendar representing the crops in Hardin County. The study area is located 14 kilometers (8.5 mi.) northwest of Eldora, Iowa, with the center point at latitude 42°25' N., longitude 93°15' W.

Hardin County was selected as a study area because it represented agriculture typical of the midwest corn belt. The fields are small to medium in size, primarily rectangular, and fall in a typical agricultural pattern. A variety of major crops comprised a relatively low contrast target on which to test the ERTS-1 sensors.

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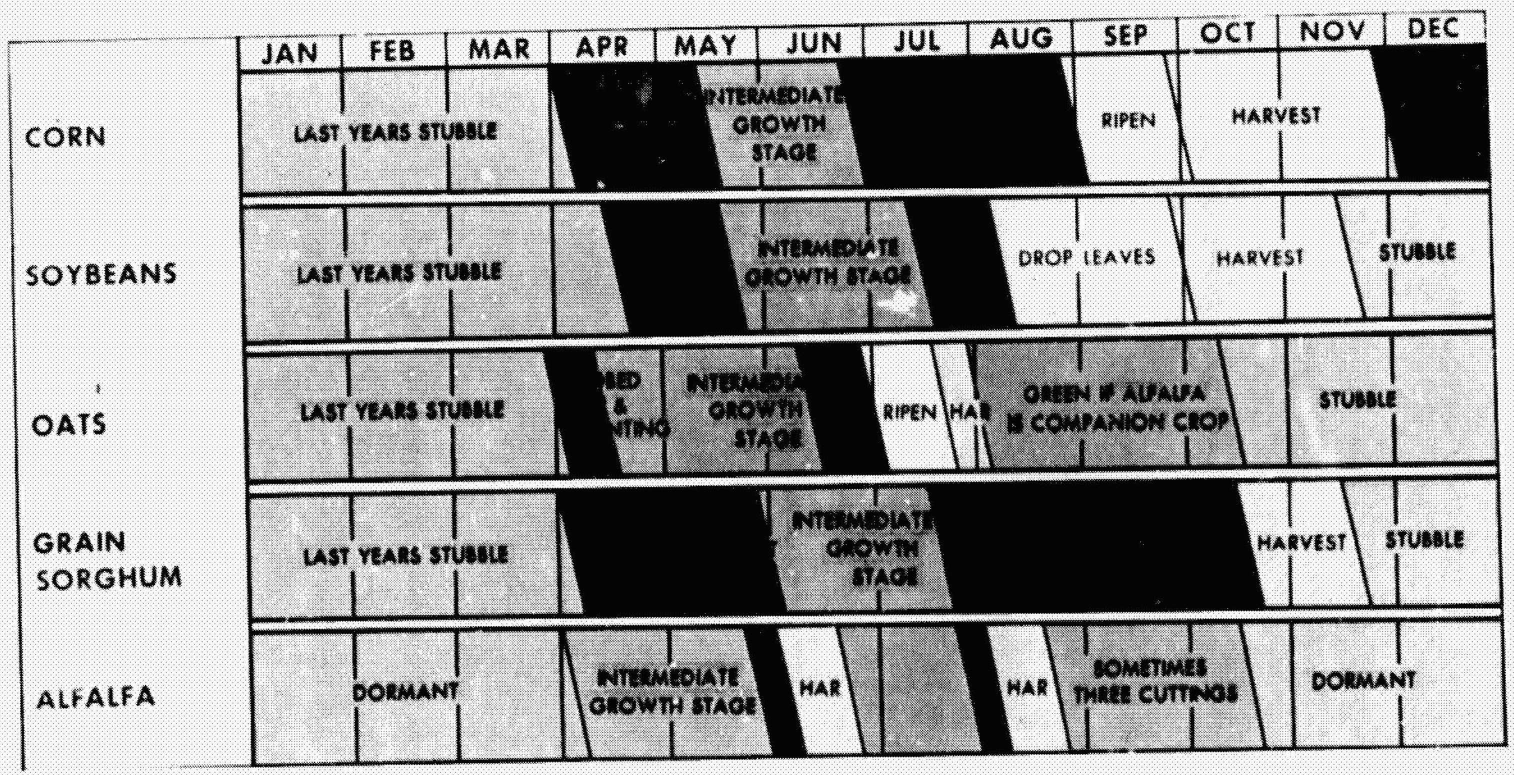

Figure 3-4.- Hardin County, Iowa, crop calendar.

Data were selected from the August 13, 1972, pass (scene 1021-16324), the only one available at the time. Part of the study area fell under a cloud shadow, but the affected area was small. All other scenes had a greater percentage of cloud cover than that selected.

3.1.4 Holt County, Nebraska

Holt County, Nebraska, is located on the eastern edge of the Nebraska sandhills and is bounded on the north by the Niobrara River. It comprises an area of 3862 square kilometers (2400 sq. mi.), of which 607 287 hectares (1 500 000 acres), or nearly 100 percent, is farmland. The average farm size is moderately large, slightly over 405 hectares (1000 acres). The crop types are limited, with corn the leading crop. Alfalfa hay ranks second, with some barley, rye, oats, grain sorghum, winter wheat, and irrigated pastureland also present. Figure 3-5 is a crop calendar showing the crop cycles for an average year. The center of the study area is 31 kilometers (19 mi.) northwest of O'Neill, Nebraska, at latitude 42°37' N., longitude 98°57' W.

The relatively high contrast features are the result of center pivot irrigation systems to convert low productivity sandy, shallow soil to productive cropland. These uniform circular irrigation patterns represent features of accurately known dimensions and area.

Holt County was selected as a test site because of the predominance of a single crop, the relatively large field size, and the unique farming and irrigation practices that characterize this area.

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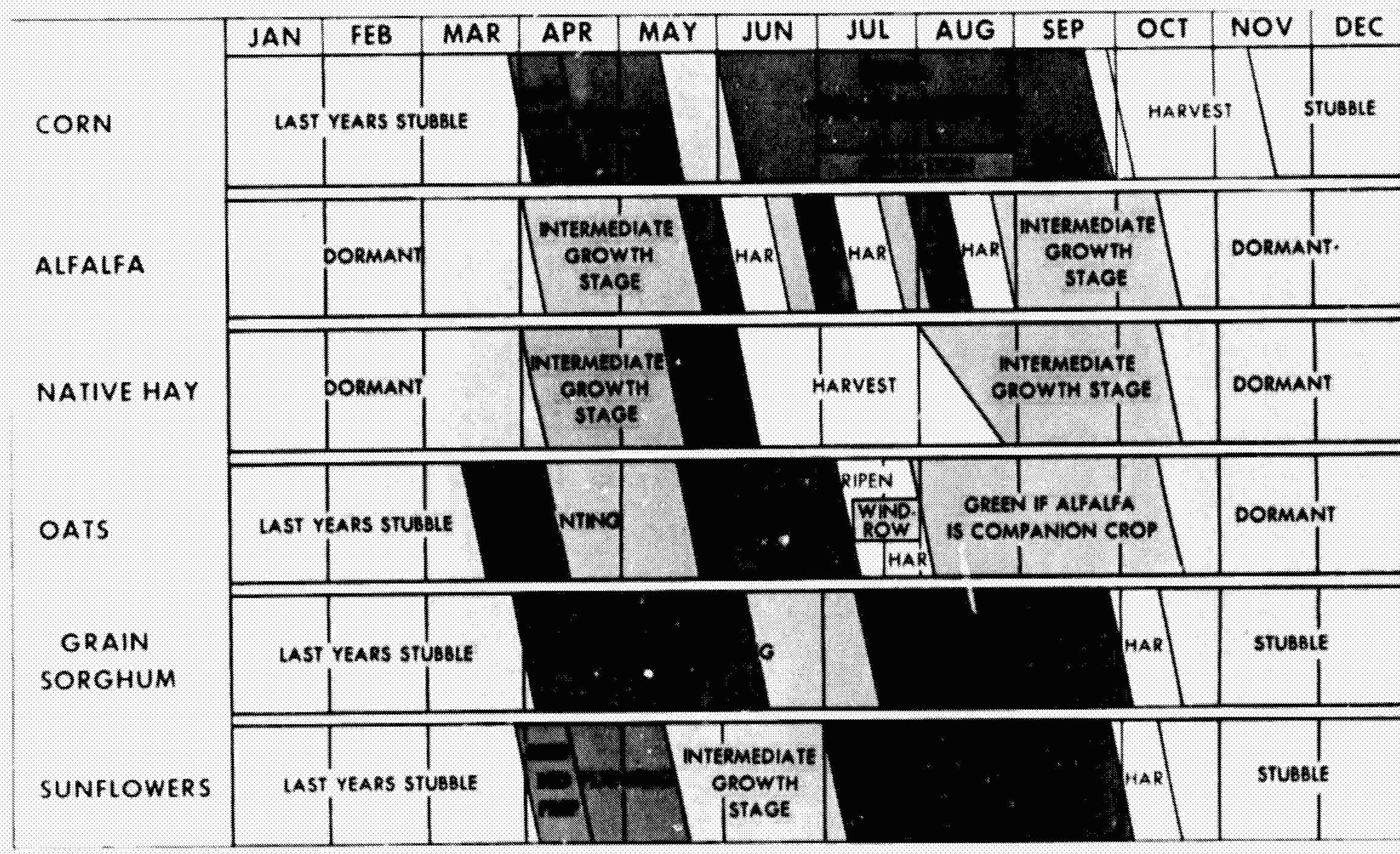

Figure 3-5.- Holt County, Nebraska, crop calendar.

Data sets from the July 30, 1972, pass (scene 1007-16551) and the August 16, 1972, pass (scene 1084-16495) were selected for single and temporal analysis.

3.1.5 Butte County, California

Butte County, California, is located in northern California, north of Sacramento and west of Reno, Nevada. Butte County covers an area of 4307 square kilometers (1663 sq. mi.), with 275 304 hectares (680 000 acres), or approximately 64 percent, comprising farmland. The average farm size is 142 hectares (352 acres). The center of the site is 20 kilometers (12.5 mi.) west-northwest of Oroville, California, at latitude 39°35' N., longitude 121°47' W.

Butte County was selected as a study area because of its large, irregularly shaped fields and the limited variety of major crops. This region of low mountains and fertile valleys has a long, warm, growing season and low precipitation. Although there is a wide variety of crops, the number of major crops is limited. Rice, tree fruits, nuts, small grains, and grain sorghum cover most of the study area. Figure 3-6 shows the crop variety and cycles for this area.

Several data passes of Butte County were sufficiently clear for analysis; however, at the time the selections were made, a complete data set was not available for an optimum time during the growing season. Further delay in starting the analysis would have been detrimental; therefore, the September 19, 1972, pass (scene 1058-18221) was selected

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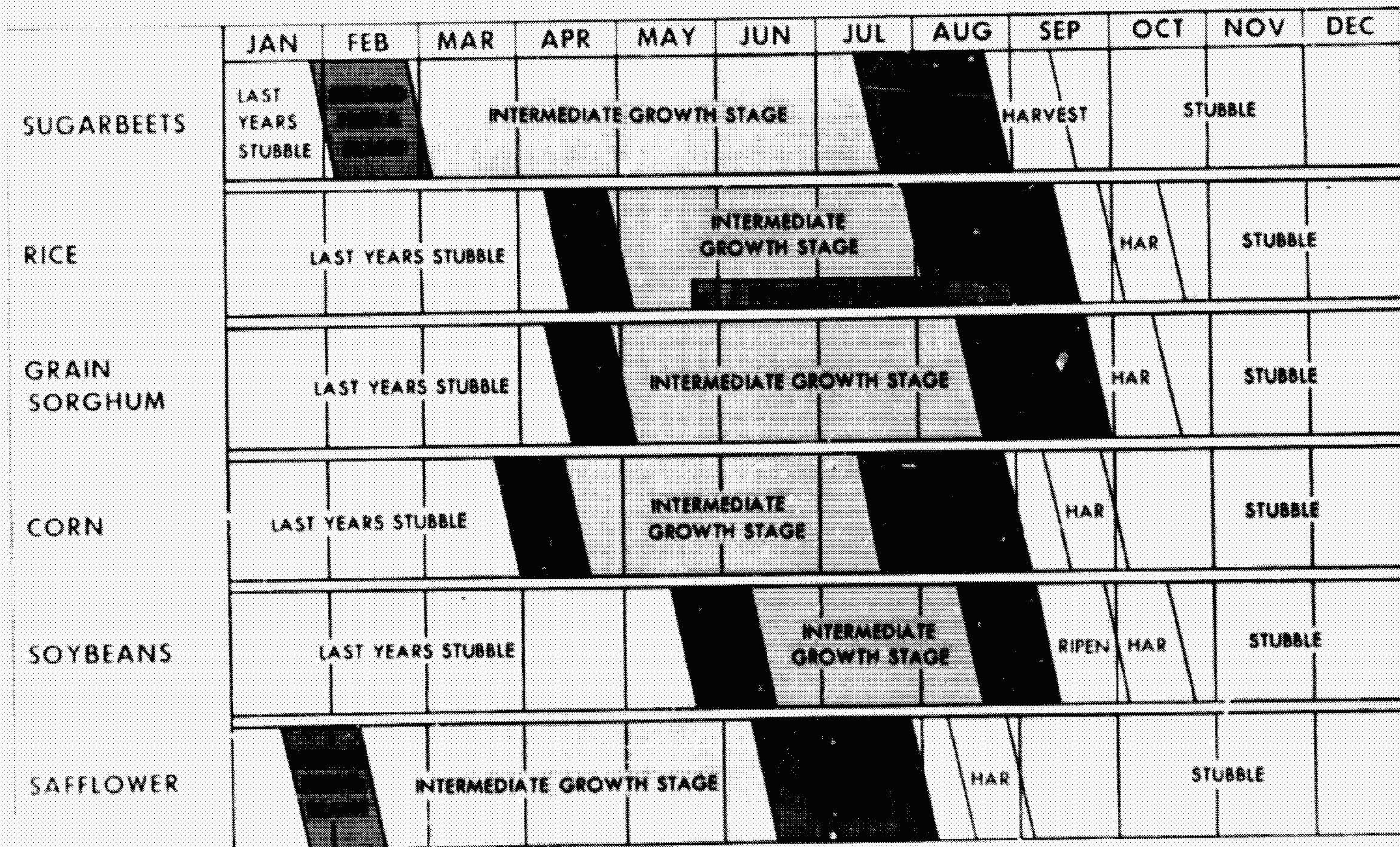

Figure 3-6.- Butte County, California, crop calendar.

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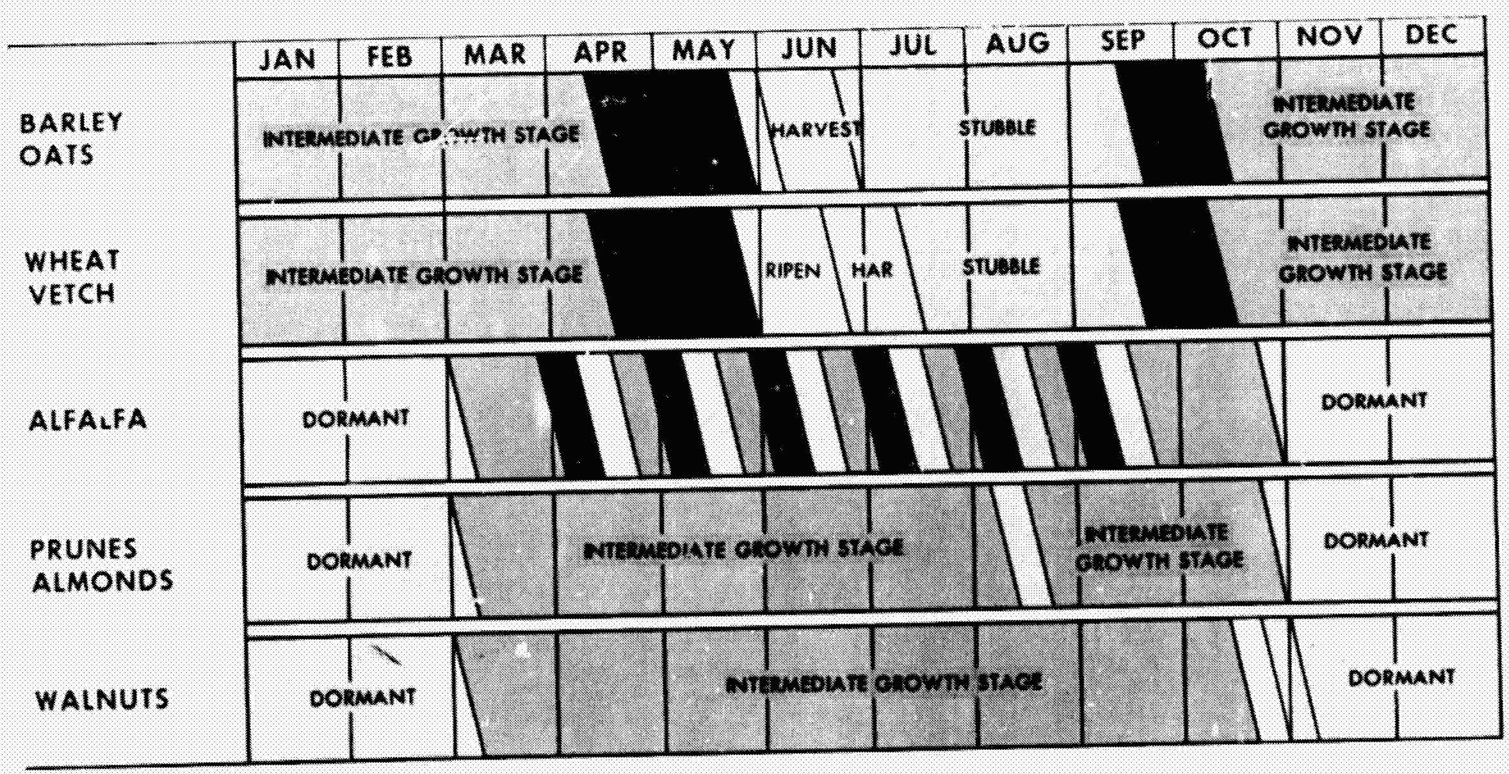

Figure 3-6.- Concluded.

because it was the earliest complete data set available. Two other data sets acquired October 6 (scene 1075-18170) and October 24, 1972 (scene 1093-18170), were used for temporal analysis.

3.1.6 Worth County, Georgia

Worth County, Georgia, is located in the southern part of the state, with the Flint River as the northwest boundary. Worth County covers an area of 817 square kilometers (508 sq. mi.) in the southern podzol soil region. Approximately 105 263 hectares (260 000 acres), or 70 percent, are utilized for farmland. The farms in Worth County are not overly large, with farms averaging 109 hectares (270 acres). The site is located 6 kilometers (3.5 mi.) northeast of Sylvester, Georgia, at latitude 31°32' N., longitude 83°47' W.

The frost-free growing season in Worth County is more than 300 days. Cotton acreage has been declining in recent years, but still remains the major crop, along with corn and peanuts. Figure 3-7 is a crop calendar representing the crop practices in Worth County.

Worth County was selected as a study area as an extreme case. The fields are very small, with field boundaries that follow the natural contours of the terrain. This combination, and the relatively low contrast crop variations, provided a challenge in attempts to analyze ERTS-1 data.

The selection of data for Worth County was the earliest, cloud-free data set (September 8, 1972, scene 1047-15382).

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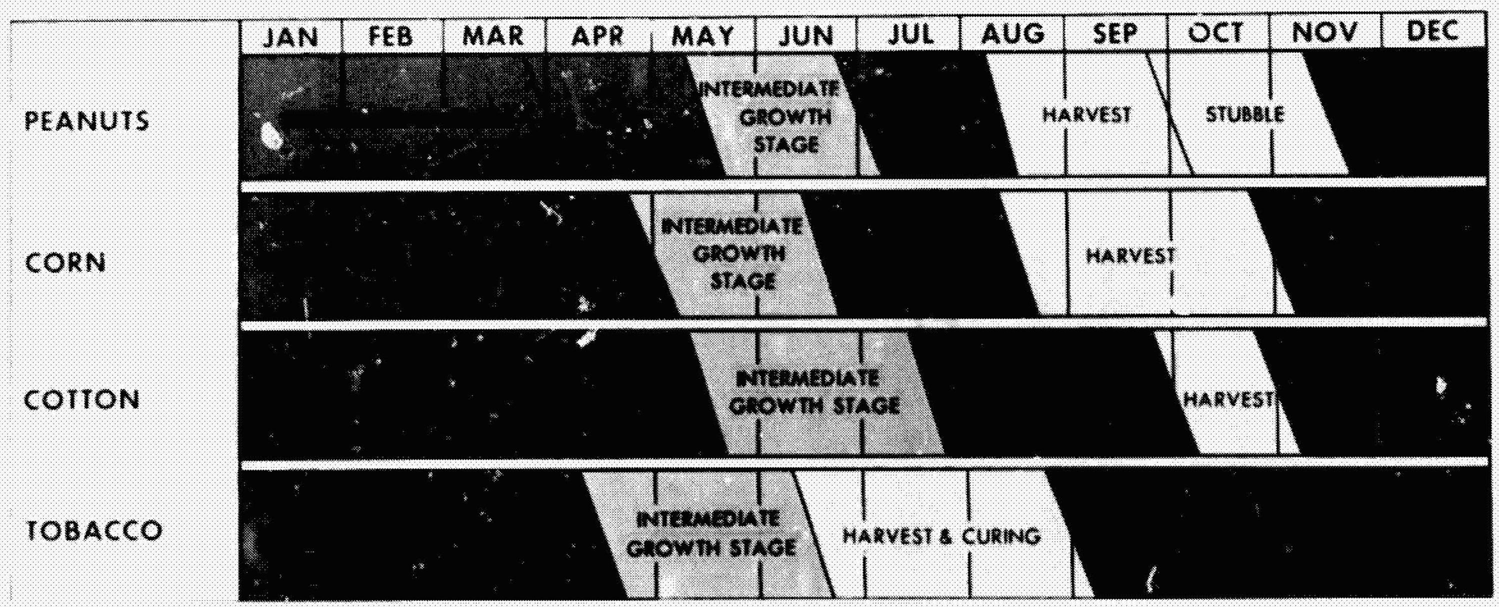

Figure 3-7.- Worth County, Georgia, crop calendar.

3.2 DATA PROCESSING

The following sections provide a generalized approach to the processing of the ERTS-1 data for the six agricultural test sites. Since this was one of the first attempts at analyzing ERTS data, no optimum procedures had been established. Consequently, the team objective was to obtain the most information from the data by any conceivable means. Nine people worked on the project at one time or another, which resulted in somewhat different approaches in the analysis techniques for each study area. The following is a generalized approach to the processing of the ERTS-1 data for the six agricultural test sites. The specific variations to the analysis approach will be discussed in section 4, Analysis and Results.

The primary analysis was performed on MSS system-corrected (bulk) digital data tapes and imagery. The MSS system-corrected CCT's were in most cases of better quality than expected; however, much of the black-and-white imagery had limited density range. The imagery then was reprocessed by the JSC Photographic Technology Laboratory (PTL). Both conventional image interpretation and computer-aided techniques were utilized co achieve the objectives of the investigation.

3.2.1 Conventional Image Interpretation

The analysis of the ERTS-1 imagery with conventional techniques was divided into two efforts. The first approach utilized the various equipment available to make color-enhanced images from black-and-white imagery. These enhanced images were then subjected to conventional image interpretation. The second conventional image interpretation approach was to analyze color composite imagery supplied by the GSFC and color composite imagery generated in-house on the DAS from magnetic tapes.

3.2.1.1 Image enhancement.- The analysis of the image enhancements included the following tasks.

1. Classifying features within the study area to the levels presented in the hierarchy in figure 2-1; i.e., agricultural and nonagricultural, cropland and noncropland, crop classes and crop species.

2. Determining minimum feature sizes detectable as a function of shape and contrast.

3. Measuring areas of representative fields within the study area.

4. Locating fields within the study area using a conventional coordinate system such as the UTM.

Image enhancement techniques were used to investigate ERTS-1 MSS imagery for each of the six test sites. Several techniques were examined, and additive or false-color enhancements and electronic density-slicing displays were found to be the most promising. The additive color enhancements were prepared with the ACVP for film chips cut from ERTS-1 24-centimeter (9-1/2-in.) positive black-and-white MSS imagery. The ACVP is described in appendix B. Electronic density-slicing displays were prepared with the MCFV, which is also described in greater detail in appendix C.

The data flow is shown in figure 3-8. Third-generation GSFC 24-centimeter (9-1/2-in.) black-and-white positive ERTS-1 MSS imagery was received for each of the test sites. Upon receipt the imagery was screened for quality and the data sets were selected for analysis. Some of the imagery proved to be of too high average density and too low contrast and was reprocessed photographically to a higher quality (described in appendix B). The imagery was trimmed to film chips about 6 square centimeters (2-1/2 sq. in.), with the test sites centered, to fit the film gates of the ACVP. False-color renditions were generated with the ACVP and the most useful were photographed. No analysis was performed directly on the ACVP screen to minimize the length of time the imagery was exposed to the heat of the projection bulbs. Color prints were most often used in the analysis. Numerous combinations of the MSS bands, including positives and negatives, were produced to arrive at the optimum display for detection, classification, area measurement, and field location. False-color IR rendition was ascertained to be the best general-purpose additive color enhancement.

Electronic density slicing of the same data sets used on the ACVP was performed with the MCFV. Due to the inherent nonlinearity in the MCFV screen display, the enhancements were directed toward classification efforts only. Analog and digital displays were produced and the most promising were photographed for further study. Training fields were selected from the ground-truth data for programing of the digital

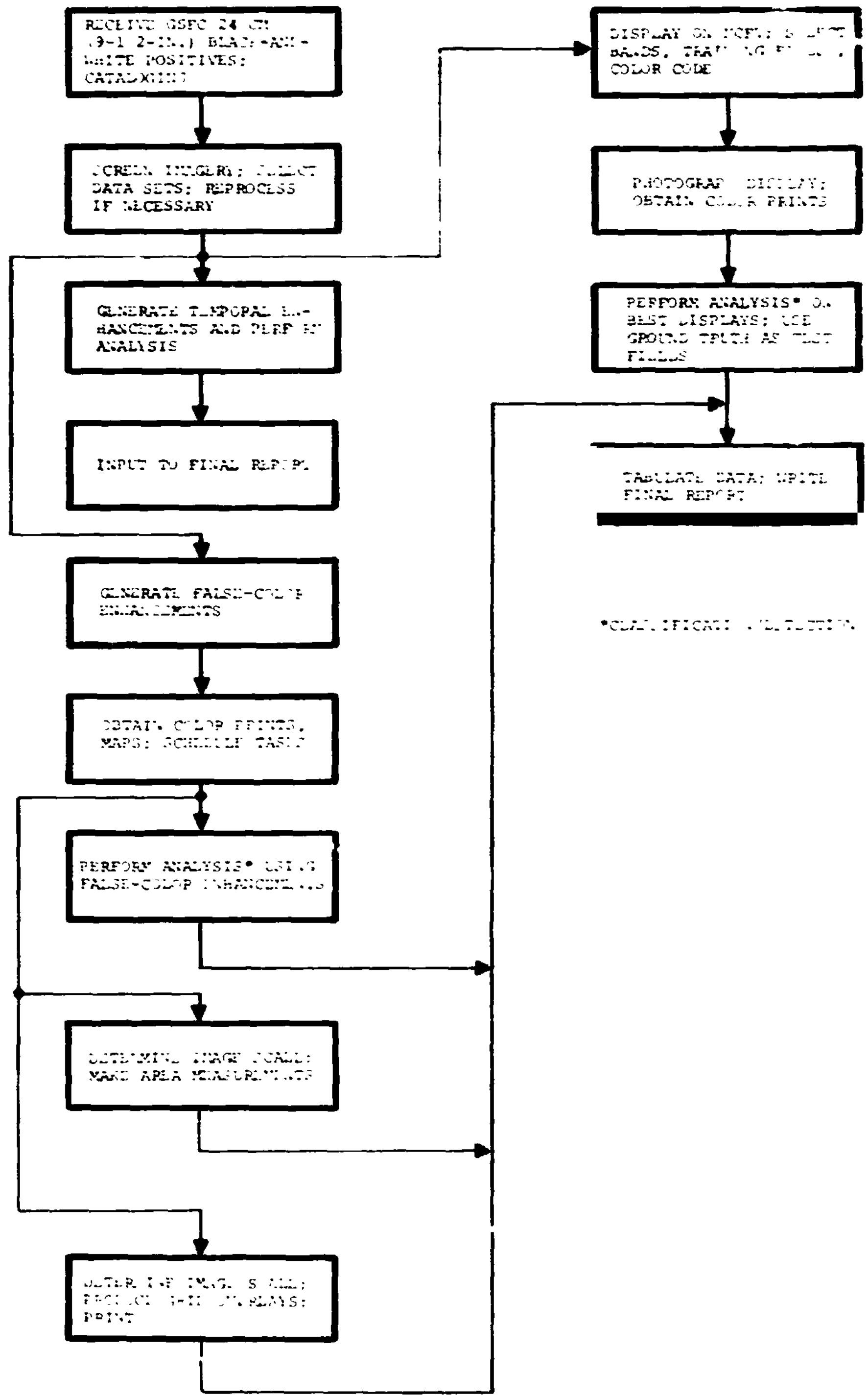

Figure 3-8.- Image enhancement techniques data flow.

color display. Although several iterations with the MCFV are normally required to achieve the most useful display, time constraints and equipment difficulties prohibited more than one iteration. The display photographs were analyzed visually, with about 0.5 day spent on each enhancement.

3.2.1.2 Color composite enhancements filmed at GSFC and on the JSC DAS.- The degree to which agricultural features could be detected, identified, and measured in the six study areas was evaluated. Conventional image interpretation techniques were applied to ERTS-1 color composites produced on the DAS, as well as to those generated at GSFC. The DAS does not classify, but merely displays the data and produces film. The tools used in the analysis of color composites included rear projection viewers, light tables, tube magnifiers, scales, and image interpretation keys.

The data were screened upon receipt. Objects in the area of interest were noted which would interfere with the interpretation, such as clouds or cloud shadows. The ERTS-1 tapes were screened on the DAS to determine any tape defects, such as data dropouts. The GSFC composites were screened on rear projection viewers to find any film defects, such as poor contrast caused during film processing.

The GSFC color composites are produced at a scale of 1:1,000,000 and contain MSS bands 4 (green), 5 (red), and 7 (IR). The JSC color composites produced on the DAS were enlarged approximately four times to a scale of 1:246,000.

The MSS-formatted tape was converted to the multispectral data system (MSDS) format so that the data could be viewed and filmed on the DAS. The MSDS tape (700 pixels wide by 2300 scan lines long) covered an area 34 by 161 kilometers (21 by 100 mi.). The scale was about 1:246,000.

Another edit tape was prepared from the MSDS format in which the data were expanded three times to enhance the information on the imagery. This covered an area on the ground which was 12 kilometers (8 mi.) crosstrack by 10 kilometers (6 mi.) along track. The study area was centered on the enlarged image. The average scale was 1:82,000.

The ERTS-1 MSS data have four spectral bands: band 4 (green), band 5 (red), band 6 (near IR), and band 7 (IR). The DAS has only three guns for display and filming (green, red, and blue). Various assignments of ERTS bands to DAS guns were used; for example, ERTS band 5 was displayed on the green gun, band 7 was displayed on the red gun, and band 4 was displayed on the blue gun to give a false-color IR rendition of the image. Another example used ERTS band 4 displayed on the green gun and band 5 on the red gun. These assignments gave a rendition as close to true color as possible. Several enhancements were filmed and the best films were analyzed. The DAS color gun intensities were computed from the histogram output of the EMBEDT program, which is a Univac 1108 EXEC II program that converts the ERTS-1 MSS tape produced by GSFC to MSDS format. These values were varied to enhance certain features and to give the best renditions for analysis.

3.2.2 Computer-Aided Processing

The ERTS-1 data were computer processed by various multispectral pattern recognition programs. Some of these programs were developed by JSC, but most were part of the system developed by LARS at Purdue University. The hardware systems at JSC which were used were the ERIPS, the Univac 1108, and the LARS remote terminal. These systems are described briefly in appendix B.

The following sections describe the generalized data flow for the computerized processing of ERTS-1 data, which is shown in figure 3-9. After receipt of the data, the ERTS-1 data tape was logged into the Earth Observations Division (EOD) ERTS data control system. The CCT's were duplicated and the originals retained. The duplicate tapes were then reformatted by a combination of several JSC conversion programs which produced nine-track, 800-bpi tapes in MSS, MSDS, and LARSYS II formats. These included the multispectral bulk edit tape program EMBEDT. Where practical, preprocessing also included the generation of an edit tape containing only the data in the study area to be analyzed.

Gray maps were generated from either the PICTOUT subsystem of LARSYS, or SCERTS, a data-screening program developed at JSC. These gray maps were used in correlation with

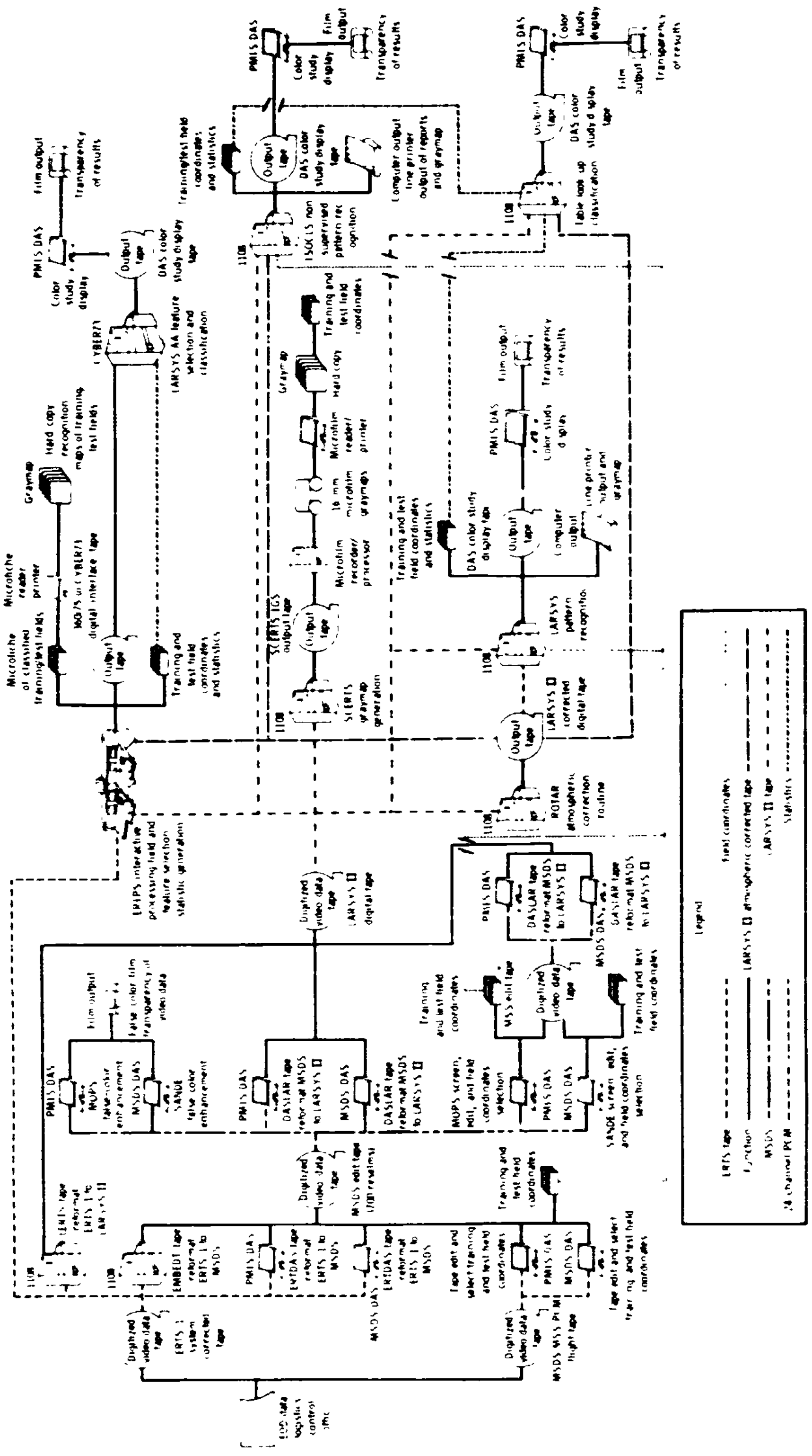

Figure 3-9.- JSC ERTS-1 data processing flow.

base photography and ground truth to define training and test fields, and to locate them by line and sample coordinates.

The LARSYS statistical processor CLASSIFY was run with selected training data. The Univac 1108 program ISOCLS was then run on both the complete study area and the selected training fields to cluster each class of training fields by similar spectral characteristics to determine the need for subclasses. If the need for a subclass in any given class was found to exist, CLASSIFY was run again, including among the original classes the newly determined subclass. Output from the ISOCLS run was a cluster map printout, a card deck containing cluster statistics, and a nine-track, 800-bpi tape in DAS color study format. The output from the LARSYS statistical processor CLASSIFY was a classification character map printout and a DAS tape. The tapes were displayed and viewed on the DAS and a film record was made. The results of the LARSYS data processing were studied. This included comparing these results with those from the conventional image interpretation analysis.

3.2.3 Ground Data Acquisition

Personnel from NASA-EOD held workshops for ASCS county personnel prior to the beginning of the project to familiarize them with image interpretation techniques. In addition, ground-truth acquisition was discussed and plans were developed to furnish JSC with the data necessary to implement the project.

The collection of ground-truth information for the investigation consisted of annual and periodic observations. Annual observations were made once during the 1972 growing season for all fields in the 19-square-kilometer (12-sq.-mi.) intensive study area of each study area. Periodic observations were made every 18 days coincident with the local ERTS overflight for 25 to 50 selected training and test fields within each study area.

Both the annual and periodic observations were recorded on a ground-truth summary form (tables C-III to C-V) and submitted to JSC. Both observations were collected by USDA-ASCS personnel in each county. For each observation the section number, ASCS photo number, farm number, field number, acreage in field, crop species, estimated crop height, stage of maturity, and row direction were entered on the ground-truth summary for each field. Existing ASCS farm and field numbers were used. All fields operated by one farmer in the study area were considered as a farm.

For the annual ground-truth observation, ASCS furnished black-and-white 1:7,920-scale base photography of the 19-square-kilometer intensive study area in each of the six counties. The photography was annotated with farm number, field number, and the acreage of each field. Farms were outlined in blue and fields in red.

The annual ground-truth observations for each of the intensive study areas are depicted as color-coded charts in figures 3-10 through 3-15.

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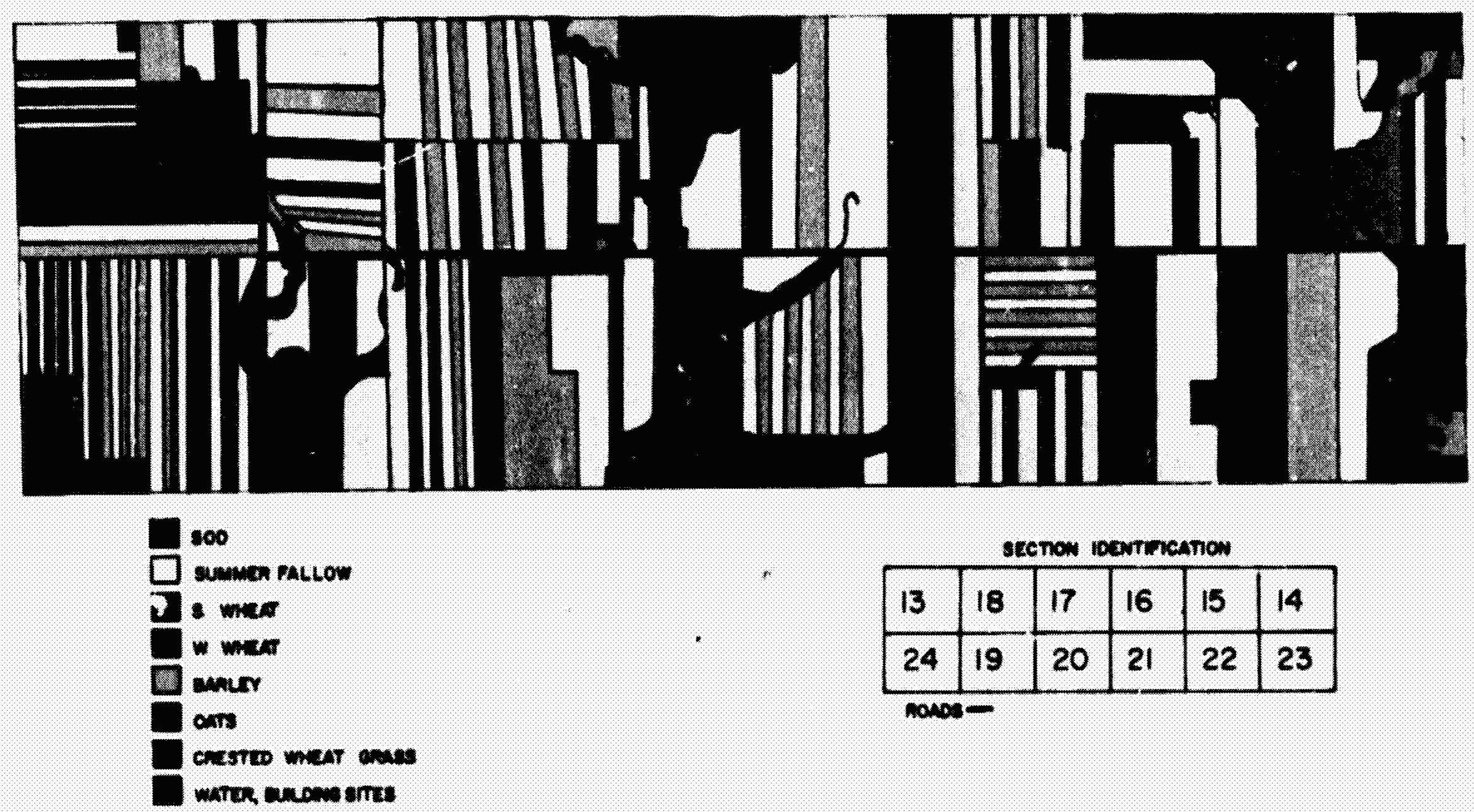

Figure 3-10.- Hill County, Montana, 1972 annual ground truth.

NASA S-73-25512

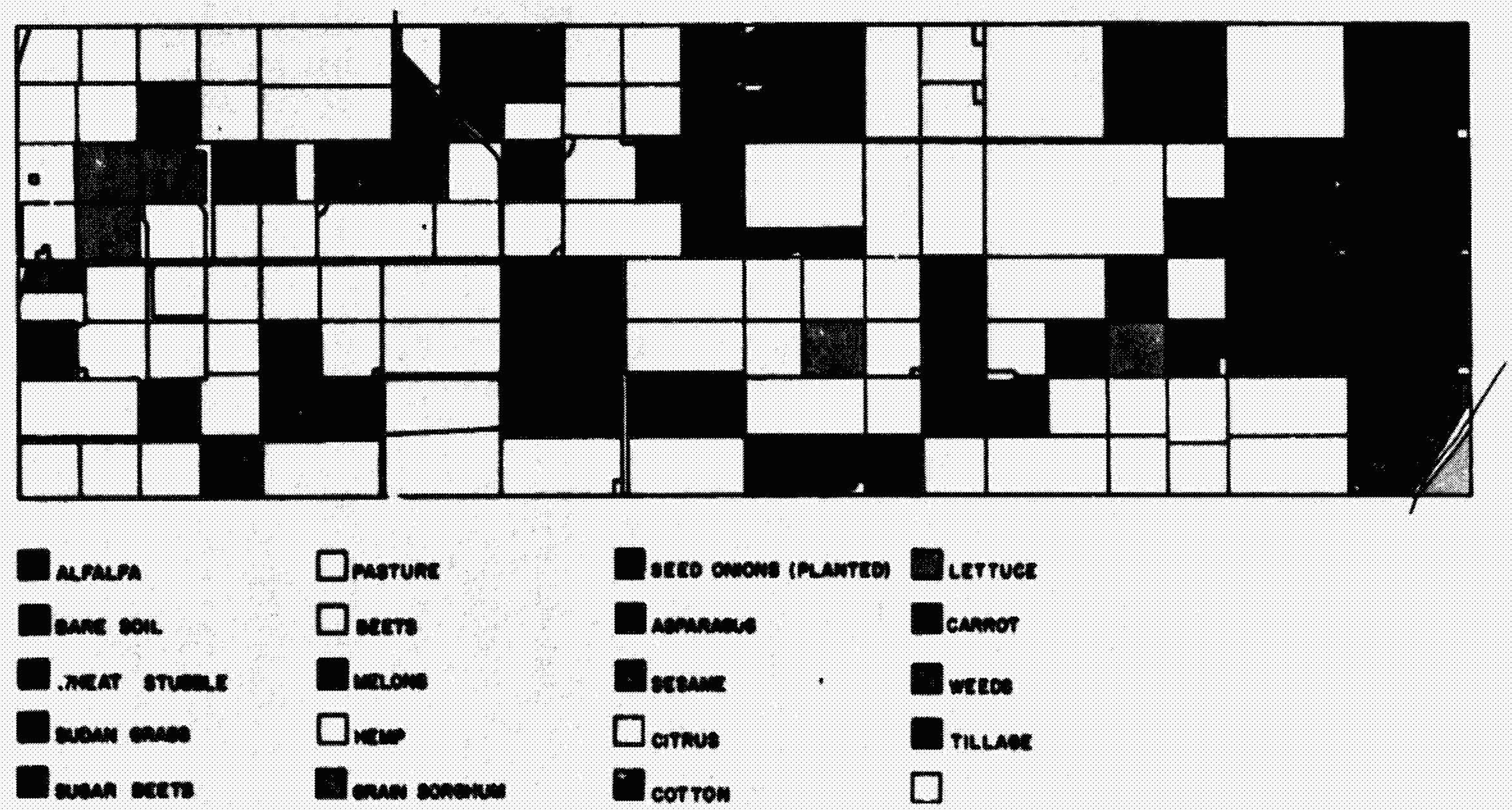

Figure 3-11.- Imperial County, California, annual ground truth collected November 6, 1972.

NASA S-73-25510

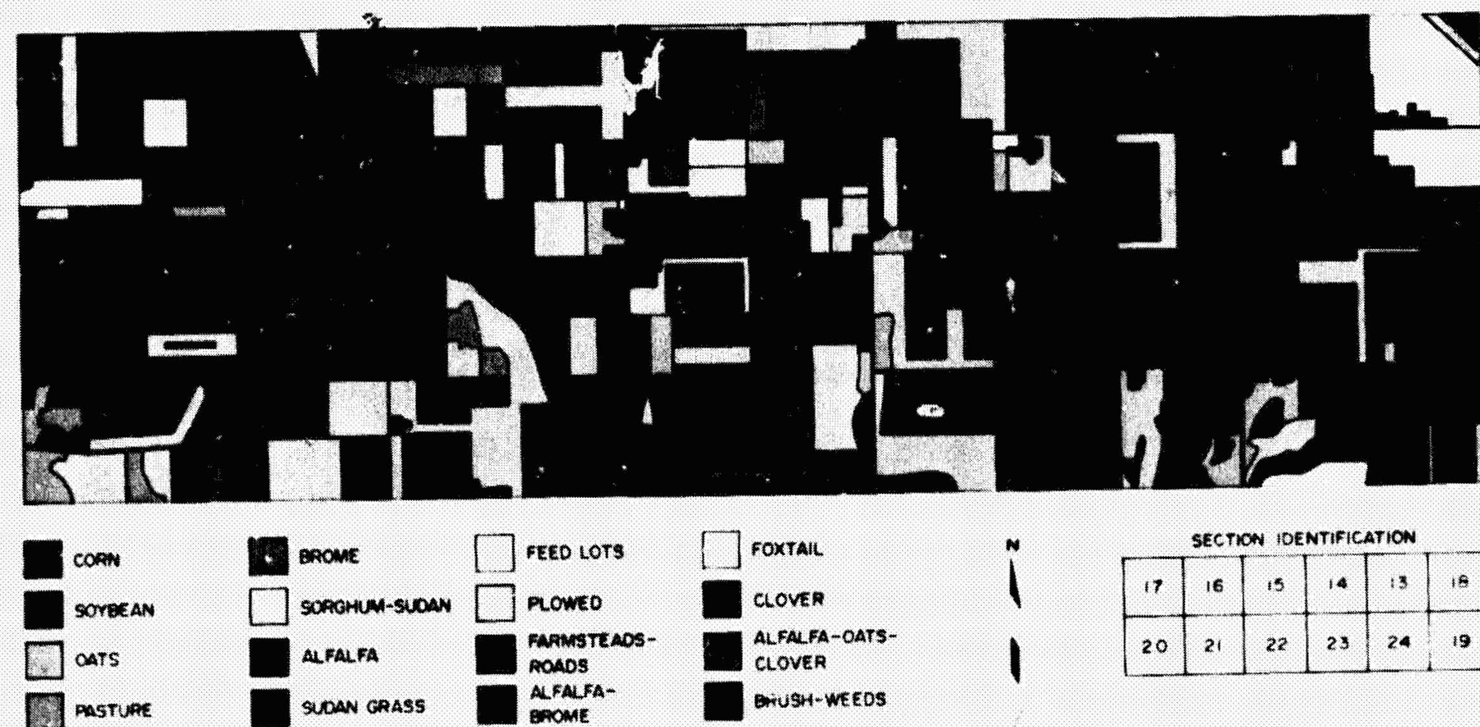

Figure 3-12.- Hardin County, Iowa, annual ground truth collected July 26, 1972.

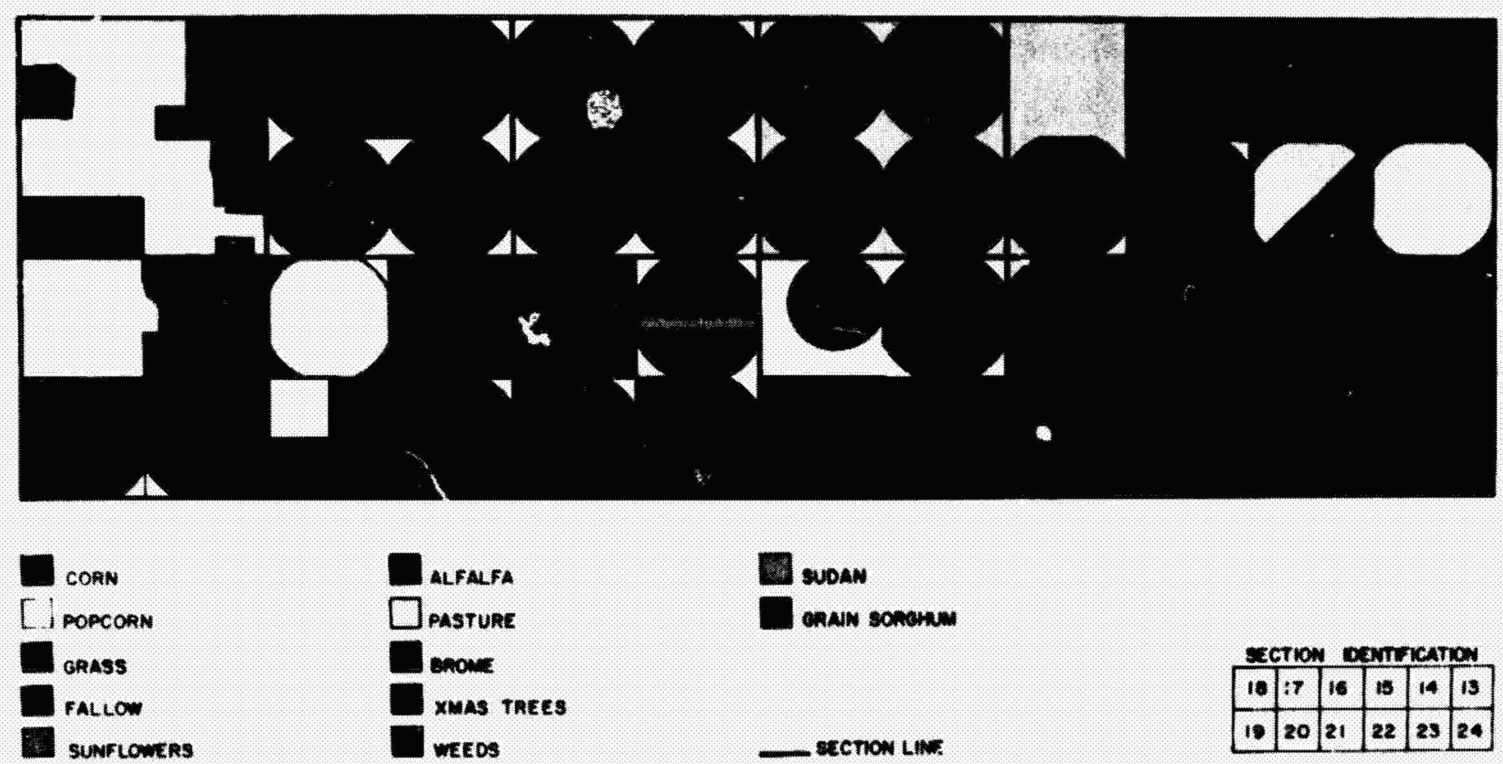

Figure 3-13.- Holt County, Nebraska, annual ground truth collected July 28, 1972.

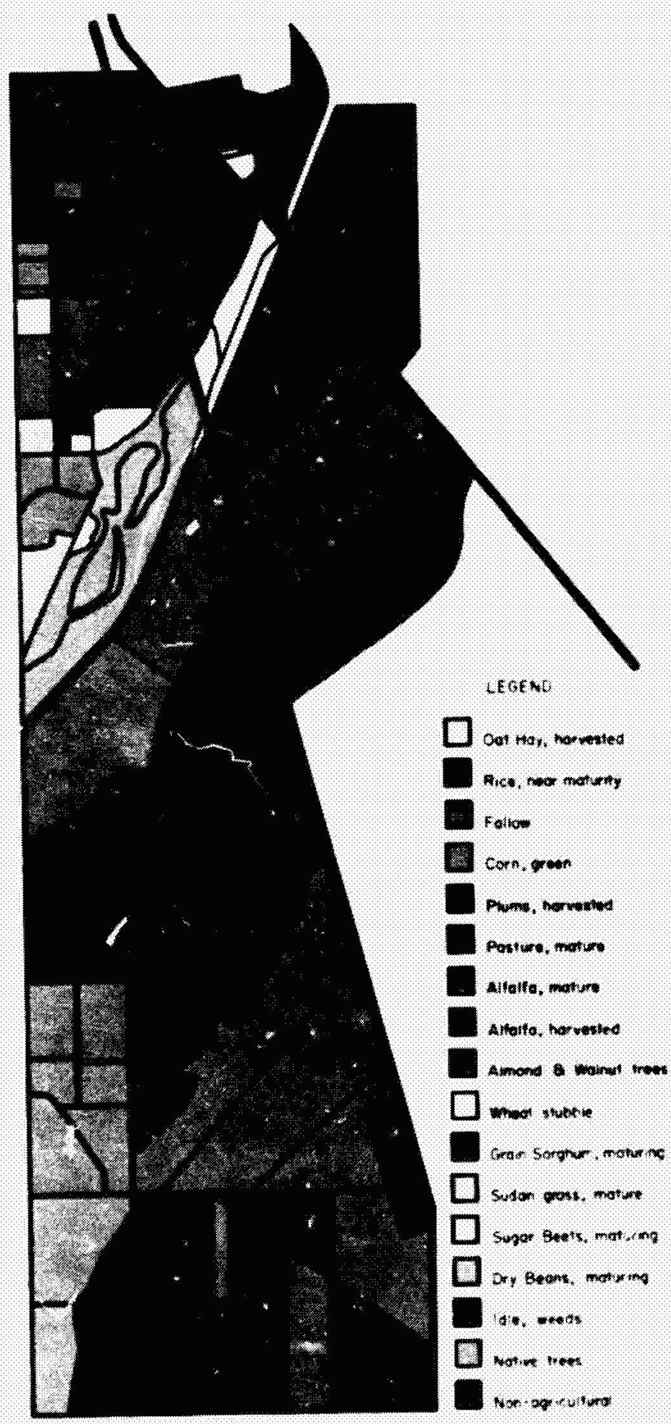

Figure 3-14.- Butte County, California, annual ground truth collected August 10, 197?.

Figure 3-15.- Worth County, Georgia, annual ground truth collected August 18, 1972.

3.2.4 Area Measurement

Area measurements were made of selected fields to determine the feasibility and limitations of enhanced ERTS imagery and conventional area measurement techniques. Although other techniques were considered, the most practical approach from the standpoint of available manpower, time, and instrumentation was false-color enhanced ERTS-1 imagery and a photographic data quantizer. A description of the data quantizer is presented in appendix B. All area measurements were made from ACVP enhancements of about 1:130,000 scale. Color prints on a stable resin-coated photographic paper were used after a test determined that results were as accurate as measurements made from transparency material. The areas of selected fields from each test site were measured, chosen as representative of the various field conditions found within the test site. The actual area of each field was taken from ground-truth data supplied by the ASCS. One well-defined field of known size in each site was used to calibrate the precise scale of the enhancement used. Five or six area readings per field were made and averaged to minimize errors. An occasional very high or very low figure compared to the average was discarded, since these generally occurred due to operator fatigue.

3.2.5 Field Location - UTM Grid

The final purpose of the analysis was to determine if the ERTS-1 imagery was of sufficient quality to allow an investigator to readily locate fields and other surface features in terms of a conventional mapping coordinate system.

The UTM system was selected as the most practical for this task. In order to maintain the geometric fidelity of the ERTS-1 imagery, the ACVP false-color enhancements were ascertained to provide the optimum enlargements for use as base photography. Previous studies determined that no single MSS band provided an overall definition of surface features superior to the enhancements. The low distortion characteristics of the ACVP optics were also considered an advantage.

The false-color enhancements were prepared from film chips cut from the 1:1,000,000-scale system-corrected ERTS-1 imagery. The imagery was GSFC third-generation black-and-white positives for Imperial County. Fifth-generation imagery reprocessed to a higher quality was used for Hill County. The scale of each enhancement was determined by locating identifiable points on the enhancements and on a USGS map of the site area and comparing the measured distances on each. The results showed that each enhancement was approximately 1:130,000 scale. Based upon this, the fastest, easiest, and yet most accurate approach was to prepare a family of grids of slightly different scales centered about the scale of 1:130,000. The appropriate grid for a site could then be selected by precisely locating three or four points of known UTM coordinates on the enhancement and overlaying each grid until the best fit was obtained.

The grid overlays were prepared on a programed Gerber XY-plotter directly onto a high-contrast film. The scale factors were obtained from the enhancements, on which several UTM coordinates had been plotted. Contact duplicates of the grids were made photographically for use with the test site enhancements. Grid increments of 1000 meters were selected to minimize the amount of interpolation between grid lines.

Locating a sufficient number of common points on the maps and the enhancements to obtain a best grid fit proved to be difficult in some areas due to lack of map or image detail. The Hill County grid, for example, was prepared using only four points. Additional reference points would be useful for assessing the presence of distortions in the imagery. However, no significant distortions were found to be present in the imagery of the areas that were checked.

4.0 ANALYSIS AND RESULTS

The results of the investigation showed that ERTS-1 data generally could be used for crop classification, location, and area measurement. Although applications procedures must be developed, good classifications were achieved from the digital data processed by clustering programs and the LARSYS programs.

Spatial information contained in the imagery was used primarily at the agricultural-versus-nonagricultural level of classification (Level I). Generally, nonagricultural areas were either irregular in shape, showed as line features, or had a reflectance characteristic similar to water or soil. On the other hand, agricultural areas tended to exhibit regular shapes and a high IR reflectance if crops were growing.

Cropland was distinguishable from noncropland (Level II), because virtually all cropland consisted of either regularly shaped fields or well defined and obviously manmade boundaries. The presence of other clues, such as canals, location with respect to other fields, and similarity to known cropland, was also useful. The ground-truth maps of all the counties (figs. 3-10 to 3-15) show the distinct field boundaries.

Five general categories were delineated on a color IR composite overlay: cropland, grassland, water, woodland, and flood-plain vegetation. Of these, only cropland was obviously agricultural and was defined as manmade cultivation features.

The separation was based on location, association, shape, and pattern, as well as spectral response. Straight lines and rectangular shapes were assumed to appear primarily in cropland. The crop-fallow cultivation practice in Hill County and the unripened wheat area in Canada produced a distinctive pattern on ERTS imagery, as seen in figure 4-1.

Bare soil, vegetation, and water were delineated. The separation was based on relative reflectance in the different bands of ERTS imagery. For example, water had a very low reflectance in the IR bands, while vigorous vegetation had a high reflectance in the IR bands. Bare soil was separated by its relatively high reflectance in all ERTS bands.

Crops with similar commercial uses and/or similar spectral reflectance characteristics were arranged into crop types such as small grains, coarse grains, grasses, and truck farm crops (Level III). The spectral information contained in the various ERTS bands was enhanced using additive color techniques with the ACVP and MCFV to accentuate the differences in reflectance properties of the various crop types. The task, therefore, was to produce an enhancement which displayed each crop type as a unique color. On the false-color IR enhancements, crop types were related as closely as possible to the various shades of red, pink, and gray. A limited number of other false-color enhancements were generated, but none proved superior to the false-color IR rendition. The electronic density-slicing technique used by the MCFV was applied to single and multiple channels of ERTS imagery in various ways to achieve an optimum display

Figure 4-1.- Hill County ERTS-1 scene 1015-17392, August 7, 1972 (scale 1:1,000,000).

for separation of crop types. Additional details are given in the analysis of each study area.

Training fields were used to devise color enhancements in which the individual crop species (Level IV) were displayed as unique colors as much as possible. The techniques were the same as for crop types. Additional approach details peculiar to the specific enhancements are given in the analysis of each area.

Detection analysis was performed independently of the classification task and involved use of the ACVP enhancements almost exclusively. Detection was performed visually and consisted of comparing the enhanced ERTS images to large-scale ground-truth photography provided by the ASCS. The smallest detectable features were located for agricultural and nonagricultural areas. Factors such as shape, contrast, and location were used as guides in the selection of features.

4.1 CONVENTIONAL IMAGE INTERPRETATION

4.1.1 Crop Classification

Crop classification was tried on all study areas using conventional image interpretation techniques. Variou enhancements produced a variety of images as described in each study area.

4.1.1.1 Hill County.- Additive false-color enhancements and density-sliced displays were prepared for the August 7, 1972, data set. Reprocessed GSFC third-generation 24-centimeter (9-1/2-in.) positives were used for each case. The data set was very poor due to image quality and to the late date in the growing season when the ERTS imagery was recorded. As in most cases, the additive color display had the higher resolution, perhaps by a factor of 2, and more of the long narrow fields characteristic of this area were visible. However, only a small number of the total fields could be investigated because the ground truth for the data set was very limited. Only the fields that were distinct enough to permit an accurate identification were analyzed.

Figure 4-2 is a recombined false-color IR rendition produced with the MCFV in the analog mode. The MSS 7 is shown as red, MSS 5 as green, and MSS 4 as blue. The poor image quality is due to the two factors mentioned above. The farming practice of having long narrow fields of alternating planted and fallow areas in this case created an additional difficulty, because at the resolution of ERTS, the narrow fields were poorly resolved on the imagery; this results in indefinite borders and a spectral quality indicative of a high proportion of mixture elements.

The visibility of a long, narrow, rectangular field was highly dependent upon its contrast with neighboring fields. Very few fields of high contrast were available for study in Hill County due to the advanced maturity of crops at the time the imagery was taken. A field of winter wheat about 62 meters (200 ft) wide with relatively high IR reflectivity was visible without difficulty. Fields 95 meters (300 ft) wide were easily seen. For detection purposes, a field of

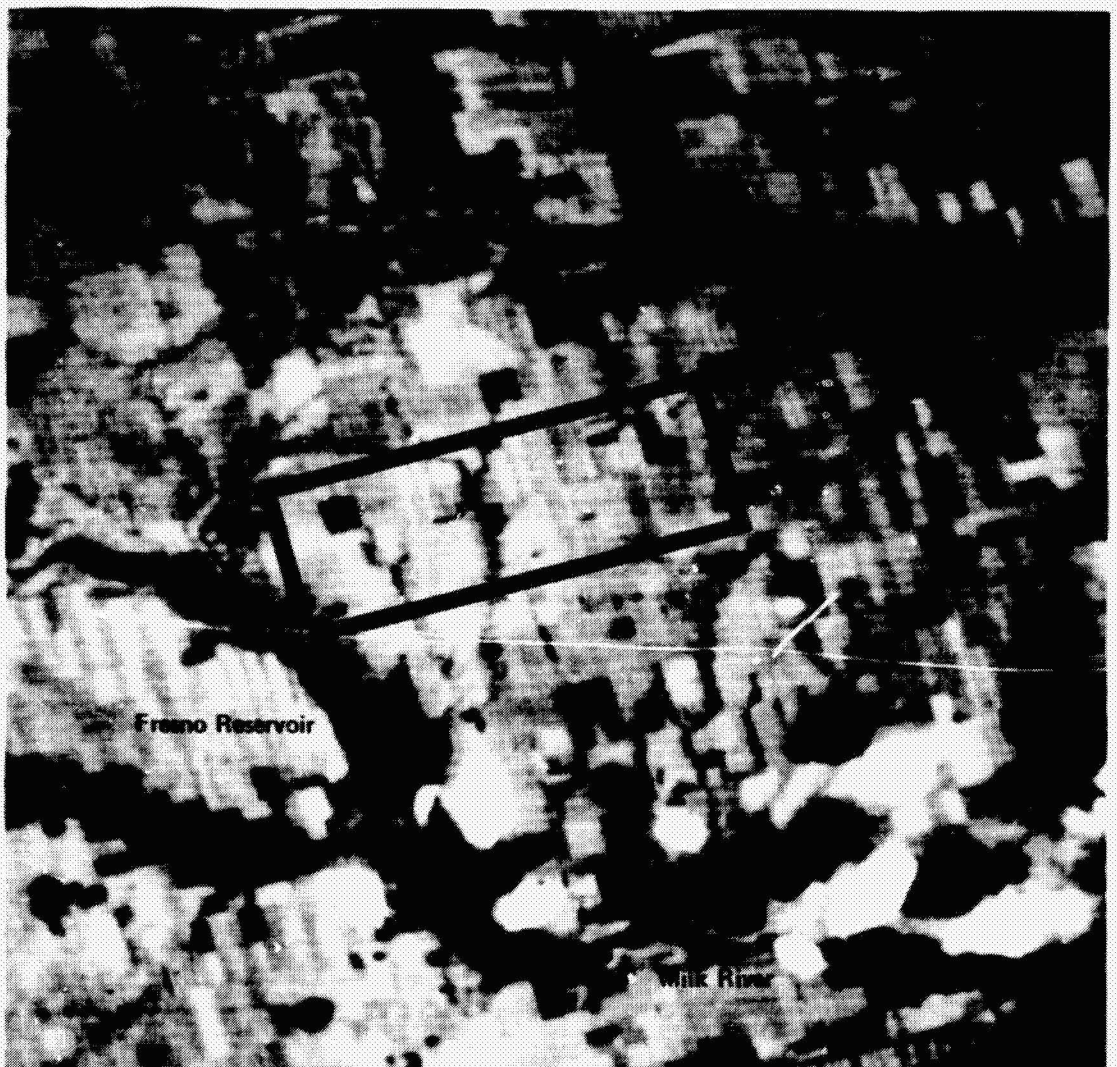

Figure 4-2.- Hill County MCFV false-color IR enhancement.

lush green vegetation bordered by fallow fields would probably be detectable to an estimated width of 50 meters (150 ft). A width of about 95 meters (300 ft) would be useful for other than detection purposes.

The degree of visibility was also dependent upon the alinement of the field to the ERTS orbit. The results given above were valid for fields running north-south. The smallest detectable field alined east-west was 140 meters (450 ft) wide and of moderate contrast. A high contrast east-west field of an estimated 95-meter (300-ft) width should be detectable.

A large number of other fields 78 to 95 meters (250 to 300 ft) wide were not detectable. These were light-colored north-south fields of harvested crops with adjacent fallow fields. Alternating fields of gray and white and of 78-meter (250-ft) average width were visible in most cases, however. A similar field 110 meters (350 ft) wide is considered useful for purposes requiring more than just detection.

A two-lane paved highway (shown in fig. 4-2) is visible as a dark line that can be followed without much difficulty. It is easiest to see when it bisects light-colored fields. The few small scattered homesteads in the area were not visible. The coulees or water drainage channels were easily detectable as either dark lines or areas with a vigorous vegetation response.

Separation of the agricultural from the nonagricultural land in the intensive study area was not difficult if one had a general knowledge of the farming practices and type of terrain in this sector of the country. Almost all fields in the test site were geometric figures bounded by straight lines due to the strip-fallow farming methods. An examination of figure 4-2 shows that over 90 percent of the study area is agricultural. The remaining few percent consist mostly of dark and somewhat irregular features known as coulees, or steep-walled water erosion paths which occur in this county. In some cases, unusually vigorous vegetation is another clue to the presence of a coulee.

The identification of crop types was not meaningful for this site because only one class of crops was grown, small grains. All the small grains in this area appear as some shade of red or pink, which is an indication of crop maturity. Harvested crops and bare soil appear as white or gray.

Classification of the crops by species would probably not have been possible if spectral signatures of the green leaves alone had been used. Because all the crops (barley, oats, and wheat) are grasses, their spectral difference shown by reflectance data varies only a small percent in the near IR. This data spread becomes meaningless when the various climatic conditions and growth stages are considered. However, the factor which contributes to their classification is the difference in planting dates and maturation dates.

In view of this, refer to the data in table 4-I in the next-to-last column. The data show the following.

1. Barley appears white in 50 percent of the cases, light red 25 percent, and medium red 25 percent.
2. Winter wheat appears light red 67 percent and medium red 33 percent.

TABLE 4-I.- HILL COUNTY DISPLAY COLOR AND GROUND TRUTH

Farm no.	Field no.	Area, acres	Crop	Est. crop height, cm	Stage of maturity	Display color[a]	
						Analog	Digital
N2	1	43	Barley			?	Bl
N4	5	19	Summer fallow			Gr	?
N4	8	22	Barley			W	C
N4	25	20	Barley			W	C
N4	34	79	Winter wheat	67.1	Ripe	LR	R-C
N5	4	79	Summer fallow			W	C
N6	2	172	Spring wheat	51.8	Ripening	LB	R-C
N7	8	41	Sod			B	O
N7	10	17	Spring wheat	54.9	Milk	MR	R
N7	12	24	Oats			Gr	G-O
N8	1	26	Barley	61.0	Ripe	LR	R-C
N8	4	54	Spring wheat	61.0	Dough	MR	R
N9	1	66	Summer fallow			W	Bl
N9	2	27	Crested wheat grass	24.4	Ripe	B	O
N9	7	25	Spring wheat	61.0	Dough	MR	?
N10	8	41	Spring wheat	61.0	Ripening	?	R-G
N11	2	139	Barley	61.0	Ripe	MR	R
N12	2	160	Summer fallow			Gr	G-O
N14	2	154	Winter wheat	61.0	Ripe	MR	R
N15	13	33	Summer fallow			Gr	G
N20	1	52	Winter wheat	61.0	Ripe	LR	C

[a]Color code - MR, medium red; LR, light red; LB, light brown; B, black; W, white; Gr, gray; R, red; O, orange; Bl, blue; C, cyan; G, green; R-C, red/cyan mix; G-O, green/orange mix; and R-G, red/green mix.

3. Spring wheat appears medium red 75 percent and light brown 25 percent.
4. Oats appear gray in 100 percent of the cases.
5. Summer fallow is gray in 60 percent of the cases and white 40 percent.
6. Sod and crested wheat grass appear black.

This indicates that, although barley and winter and spring wheat cannot be separated, they are distinct from all else in the scene. The two white fields of barley have probably been harvested, since their height is not recorded in the ground truth. Similarly, the oat field has probably been harvested and appears gray. Summer fallow is always gray or white, which is probably dependent upon whether the fields have been plowed, have weeds, or have stubble. Sod and crested wheat grass were not separable.

The crop calendar (fig. 3-2) shows why barley and spring and winter wheat cannot be classified separately. The maturity of each of these crops was almost identical and some had apparently been harvested. Oats had been harvested completely by the date of this imagery. This again shows that the display colors indicate crop maturity or condition of the fallow soil. More favorable dates for obtaining imagery relative to the growing season would be of considerable assistance.

Figure 4-3 is a density-sliced digital display produced with the MCFV. MSS 5 and 7 were color coded separately and added together to give a composite. The resolution of the resulting display was about half that found on the best

Figure 4-3.- Density-sliced display of Hill County data acquired August 7, 1972 (MSS bands 5 and 7).

black-and-white imagery. One training field each was used for fallow, barley, sod, winter wheat, and spring wheat. The field colors (shown in fig. 4-3) are listed in table 4-I in the last column.

The following list is from the tabulated data giving each crop type and the color with which it was displayed. Refer to the color code at the bottom of table 4-I.

Barley - Bl, C, C, R-C, R	Sod - O
Summer fallow - C, Bl, G-O, G	Oats - G-O
Winter wheat - R-C, R, C	Crested wheat grass - O
Spring wheat - R-C, R, R, R-G	

Assuming that the displayed colors for fallow are representative of all fallow fields, three barley fields, one winter wheat, and the oat field have evidently been harvested. Because no crop maturity was given for the barley fields in the ground truth, they were presumed to have been harvested. The winter wheat, listed as ripe, must be considered an error. All other fields of barley and winter and spring wheat are displayed as red or a red mixture. The ground truth indicated that these same fields were at some stage in the growth cycle. Oats were shown as the same color as fallow; ground-truth information implied that the oats had been harvested. Sod and crested wheat grass were indistinguishable, yet different from all other classifications.

The foregoing discussion shows that a crop classification by color has not been accurately achieved. Instead, the data show that stage of maturity is much closer to being indicated by the color of the display. A much larger number of samples would be required to establish a clear relationship between maturity and color display.

Training fields were selected for each crop from the August 7, 1972, data, the most recent periodic ground data available. Fields that were not covered by the August 7th periodic ground data observation were not used because the growth stage of the crop was not reliably known. This was important because the data were acquired during the harvest season when some fields had been harvested and some had not.

For each growth stage, table 4-II shows crop color, percent ground cover, and height for small grains grown in Hill County.

TABLE 4-II.- STAGE OF MATURITY, COLOR, PERCENT GROUND COVER, AND HEIGHT FOR SMALL GRAINS (WINTER WHEAT, SPRING WHEAT, BARLEY, OATS)

Stage of crop maturity	Color of crop on the ground	Ground cover of crop, %	Crop height, cm
Bloom milk dough	Green	100	31 to 61
Ripening	Green and gold	100	31 to 61
Ripe	Gold	100	31 to 61
Harvested	Gold	75	6

Another method of conventional interpretation was the JSC color composites produced on the DAS. Figure 4-4 was used for crop detection and identification.

NASA S-73-28062

Figure 4-4.- Hill County conventional image interpretation (scale 1:82,000).

Table 4-III shows the stage of major crops in Hill County on scene date from crop calendar and from the periodic ground observations.

TABLE 4-III.- STAGE OF MATURITY OF MAJOR CROPS FOR AUGUST 7, 1972, HILL COUNTY DATA FROM CROP CALENDARS AND PERIODIC GROUND OBSERVATIONS

Crop	Crop calendar	Periodic ground observations on Aug. 7, 1972
Crested wheat grass	Intermediate growth stage. Harvest; i.e., ripe or stubble	Ripe, grazing
Spring wheat	Ripening	Ripening, dough, ripe, milk
Winter wheat	Harvest; i.e., ripe or stubble	Ripe
Barley	Harvest; i.e., ripe or stubble	Ripening, ripe, harvested
Oats	Stubble; i.e., harvested	Harvested

The colors on the DAS compositors were grouped so that each color indicated a crop type or types. Crop calendars and object characteristics, such as shape, size, pattern, site, texture, and tone, were also considered in the crop identification.

The color of each test field was noted and then found on the image interpretation key. Based on color, the fields were classified into crop types or species (fig. 4-4). The classification results for each field were compared to ASCS ground observations to determine the accuracy of crop identification. Computation of crop identification accuracy was based on the following formula:

$$\text{Accuracy of field identification} = \frac{\text{Number of test fields identified}}{\text{Total number of test fields}}$$

Interpretation of the enhanced imagery (fig. 4-4) revealed that the relative contrast of adjacent features and their geographical orientation were important in ascertaining their detectability. Linear features (long narrow fields) parallel to the scan lines on an MSS image were more difficult to detect and define. Most of the fields had already been harvested, which left little contrast between the cropped fields and fallow fields. Fields 95 meters (300 ft) wide oriented north-south were detectable. The narrowest field detected with an east-west orientation was 135 meters (450 ft). Table 4-IV shows the results of the crop identification and the percent of accuracy.

TABLE 4-IV.- HILL COUNTY CONVENTIONAL INTERPRETATION OF ACCURACY OF CROP IDENTIFICATION

Crop	Number of fields				
	Test fields	Training fields	Test fields	Crop identified	Accuracy of crop identification, %
Summer fallow	91	11	80	70	88
Barley	34	7	27	16	59
Winter wheat	27	6	21	9	43
Sod	23	1	22	20	91
Spring wheat	22	7	15	5	33
Crested wheat grass	8	2	6	4	67
Oats	8	2	6	1	17
Total	213	36	177	125	71

4.1.1.2 Imperial County.- Several image enhancements were examined in detail to determine whether a relationship existed between crop types/species and color presentation. The enhancements were made with the ACVP and the MCFV, which will be discussed separately. Input imagery in each case consisted of unreprocessed GSFC third-generation 24-centimeter (9-1/2-in.) black-and-white positives taken November 6, 1972.

The MCFV was used to set up various MSS band combinations of density-sliced digital displays. Figure 4-5 is a combination of MSS bands 5 and 6 and was found to be the best results from the MCFV.

A brief examination of the data indicated that a correlation does not clearly exist between crop species and color presentation. Pink, for example, represents alfalfa, sugar beets, and Sudangrass. There are seven fields of alfalfa and four separate colors to represent them. A total of 21 fields are of these same colors. The classification accuracy for all alfalfa is therefore 33 percent. A similar classification shows that 9 fields of sugar beets are represented by five separate colors, with a total of 28 fields having the same colors. The classification accuracy for all sugar beets was therefore about 32 percent.

If only mature or nearly mature crops are considered, the results are somewhat better. Better results are presumably due in part to the large amount of reflectivity from the bare soil found in the fields with young seeds. There are 4 nearly mature fields of alfalfa and a total of 10 fields with the same color presentation. The classification accuracy for maturing alfalfa was then 40 percent. There were

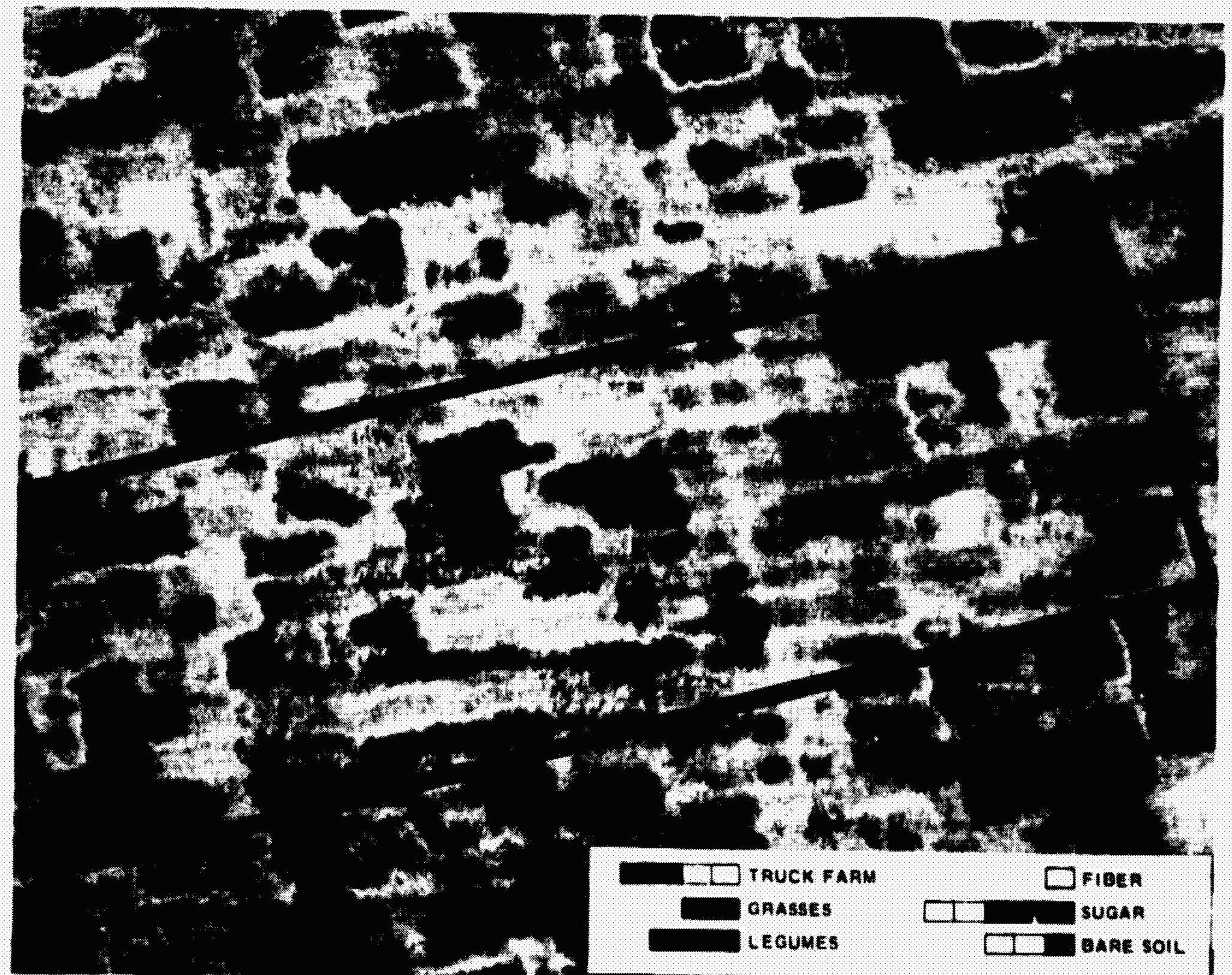

Figure 4-5.- Imperial County MCFV (MSS bands 5 and 6).

6 nearly mature sugar beet fields and a total of 14 fields with the same color representation. Classification accuracy for maturing sugar beets was therefore 43 percent.

These results are an obvious indication that accurate crop classification has not been achieved. Further manipulation of the data might reveal higher accuracies, but the category being classified would have become too broad to be useful. Even bare soil was classified correctly only 47 percent of the time. These numbers are actually meaningless if a site is analyzed in which, for example, no sugar beets were present. Classification accuracy for alfalfa might en approach 100 percent, depending on the other crops prese .. Classification accuracies as presented here are therefore primarily a function of a crop species population relative to that of some other crop. A classification accuracy of 100 percent for maturing alfalfa might mean that the technique was capable of separating alfalfa from sugar beets and Sudangrass 100 percent of the time, or only that the latter two crop types were not present at that time.

The color presentations found in figure 4-5 indicate crop condition or stage of maturity for a particular crop species rather than of the species itself.

Initial tests indicated that the MSS 5 imagery had the highest resolution of the four MSS bands. Black-and-white positive transparencies and paper prints at various scales were compared to a recombined ACVP color IR rendition to select the most usable data format for detection analysis. The color IR rendition was found to have the best overall quality due largely to the ability of the eye to distinguish subtle color differences more readily than differences in shades of gray.

The color IR rendition is shown in figure 4-6. Every separate bounded field in the test site was resolvable. The smallest such field was 6.5 hectares (16 acres), rectangular, white, bordered by contrasting fields, and easily identifiable. To detect the boundary between fields of the same contrast, a dividing border, such as a dirt road about 40 meters (132 ft) wide or greater, was required. This width was determined by measuring certain roads on large-scale aircraft photographs.

All canals and most roads that defined field boundaries were detectable. They were more difficult to see when vigorous vegetation was present along both sides of the border or when no vegetation was present. In the first case, the IR record spilled information over into the border area, while in the second case the contrast between roads and bare soil was too low. In some instances the MSS 5 band was superior in this regard.

The following results were obtained from the classification criteria discussed in section 3.2.1.

The study area was reliably classified into agricultural and nonagricultural, cropland and noncropland (fig. 4-6). Because almost 100 percent of the study area fell into these categories, an overlay was not prepared to delineate these areas. Roads and irrigation canals were the only types of features visible that were noncropland. Large-scale ground-truth photography was used for verification.

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Figure 4-6.- Imperial County conventional image interpretation ACVP false-color IR enhancement.

Crops in the test site were classified in these categories: truck farm crops (melons, carrots, asparagus, lettuce), grasses (wheat, Sudangrass, grain sorghum), legumes (alfalfa), fiber (cotton), and sugar-producing crops (sugar beets).

Figure 4-6 clearly shows the crop types were not uniquely identified by specific unambiguous colors. A similar attempt was made using various training fields to relate a particular color to just one crop species. Again, the results quickly indicated that crop classification in this manner was almost totally ambiguous. Instead, the colors in the photograph were found to indicate crop condition (table 4-V).

Alfalfa was found to appear from a bright red to a dull red, depending on the crop height. The height could probably be translated into other factors, such as vigor, maturity, or ground cover, if sufficient ground truth were available when the color-condition relationship is set up. Similar information could be obtained for potentially each crop species by using data from a larger test area and a greater number of samples taken at various times in the growing season. Because of the limited ground-truth data available for this analysis and the general scope of the study, specific color-condition relationships were not attempted. Imagery of the quality provided by ERTS-1 was considered very adequate for fields as small as 8 to 12 hectares (20 to 30 acres). A recombined false-color IR rendition, as shown in figure 4-6, proved superior to all other additive false-color combinations attempted. An image scale of 1:130,000 or larger is considered desirable.

TABLE 4-V.- IMPERIAL COUNTY CONVENTIONAL INTERPRETATION

Color	Crop species	Height, cm
Red	Alfalfa	36
	Sugar beets	30
	Sudangrass	24
Moderately red	Alfalfa	21, 15, 9
	Sugar beets	30
	Asparagus	61
Dull red	Alfalfa	15, 9
	Sugar beets	9
	Carrots	21
	Sudangrass	21
Pink	Melon	15
Magenta	Sugar beets	27, 12
Black	Bare soil (plowed or recently planted)	
White	Bare soil (undisturbed with little or no ground cover)	
Gray	Sugar beets	9
	Grain sorghum stubble	61
	Bare soil, melons	15

A JSC color composite (fig. 4-7) was made to assist the computer-aided techniques in the selection of training and test fields. A three-time expansion of the data was used to make the color composite on the DAS. The detection capabilities of this method were limited to distinguishing among bare soil, heavily vegetated areas, and sparsely vegetated areas. Variations sometimes occurred in the screening process, but such variations did not lend themselves to any form of measurement that would allow for associations with

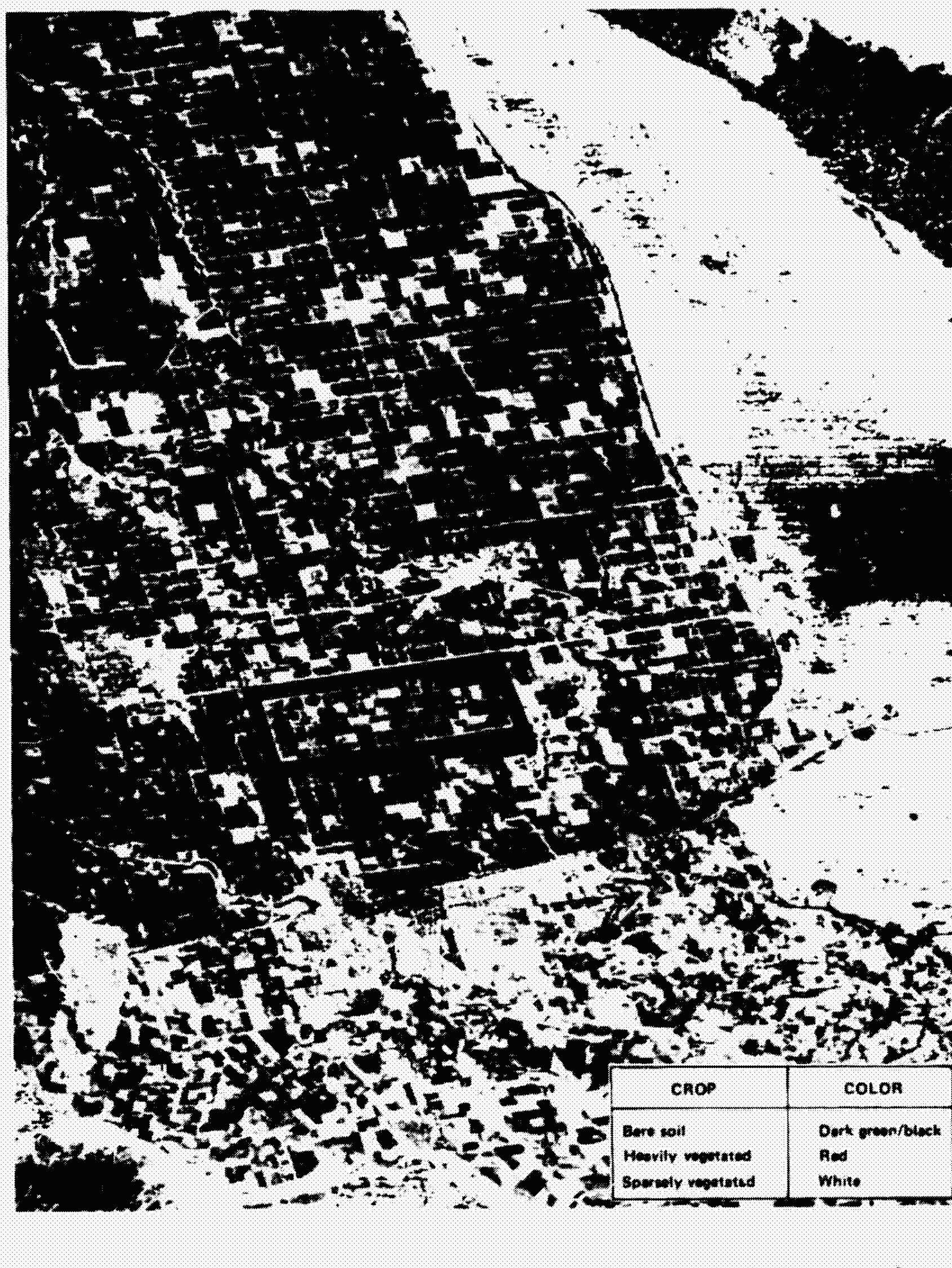

Figure 4-7.- JSC color composite of Imperial County data acquired November 6, 1972.

particular crop types. The green, red, and higher IR bands were found to be the best for detection.

Temporal analysis was attempted on Imperial County data with the MCFV using MSS 6 for November 6 and 24, 1972. Each image was sliced to provide the most usable information without spillover of data from one slice to the next, and a different color code was set up for each date. With a combination of the two images additively, it was hoped that each of the various crops would be presented as a unique color. This was not achieved, although some change in crop condition occurred during the 18-day separation. The same temporal analysis was attempted on the Butte County data with better results (sec. 4.1.1.5).

4.1.1.3 Hardin County.- The ERTS-1 MSS imagery taken August 13, 1972, was used as the data set. Additive false-color IR renditions and density-sliced displays were generated, although optimum enhancements were not achieved due to their poor quality. The false-color IR rendition had the best resolution, and field location was much easier and more accurate. Color balance was found to be irregular on the color prints. Setup of the MCFV proved difficult, and for the best results two density-sliced displays were needed for a single analysis.

Correctly locating the individual fields proved to be a lengthy task and involved much correlating with aerial photography and ground-truth data. Field location was established correctly for perhaps 90 percent of the fields used in the analysis. Conventional image interpretation techniques were used on the DAS color composites to identify those fields which could be detected.

Table 4-VI shows the stage of maturity of major crops in Hardin County for the selected scene date from the crop calendar and from ground observations.

TABLE 4-VI.- STAGE OF MAJOR CROPS FROM CROP CALENDAR AND FROM PERIODIC GROUND OBSERVATIONS

Crop	Crop calendar Aug. 13, 1972	Periodic ground observations Aug. 11, 1972
Corn	Tasseled 100% ground cover	Eared tasseled; tasseled
Soybeans	Drop leaves	Blooming
Oats	Harvested	Clipped regrowth, plowed, new seeding; ripe crinkled over, mowed, weedy
Grain sorghum	Head 100% ground cover	Green growing
Alfalfa	Harvest	Hay baled, weedy

The best DAS color composite (fig. 4-8) was used for crop identification. The ERTS band 6 was on the green gun, band 5 on the red gun, and band 4 on the blue gun. A cloud shadow just to the south of the study area obscured the northern edge.

Table 4-VII shows the colors that were grouped for each crop type. The crop types were identified according to color. The three crops and bare soil make up 85 percent of the study area.

A problem existed with the minor crops. Sorghum and Sudangrass closely resemble soybeans, and these are usually classified as soybeans. The other minor crops were very difficult to identify, partly because most minor crops were in small fiel..

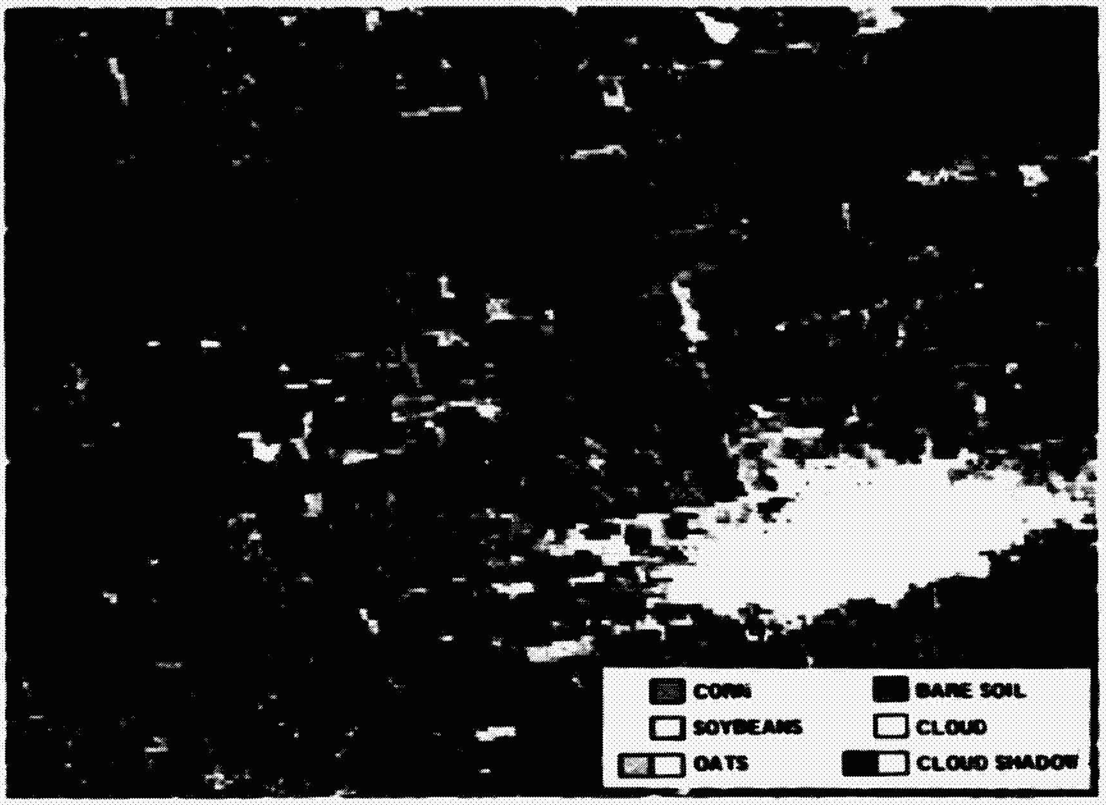

Figure 4-8.- JSC color composite of Hardin County data acquired August 13, 1972.

TABLE 4-VII.- CONVENTIONAL IMAGE INTERPRETATION OF HARDIN COUNTY

Crop	Color	Total fields	Training	Test	Test field identification	Accuracy, %
Corn	Dark green	89	12	77	73	95
Soybeans	Bright green	75	10	65	61	94
Oats	Lighter red and pink	62	14	48	41	85
Bare soil	Dark red	3	1	2	2	100

$$\text{Accuracy of field identification} = \frac{\text{Number of test fields identified}}{\text{Total number of test fields}}$$

4.1.1.4 Holt County.- The data set for July 29, 1972, was used to produce image enhancements on the MCFV. The GSFC third-generation 24-centimeter (9-1/2-in.) positives were reprocessed to a high quality for use. The ACVP enhancements were made, but were not used for this portion of the analysis because the MCFV analog plus digital display provided a good example of the combination of the two MCFV modes.

Figure 4-9 is a false-color IR rendition produced in the analog mode of the MCFV. The density-sliced digital display mode was used to single out a field of sunflowers and was superimposed on the analog display. The MSS band 4 was displayed as blue, MSS 5 as green, MSS 6 as red, and MSS 6 digital as yellow on one density slice only. A list of the crop species as presented in the ground-truth data was prepared, and the color of each species as shown in the subject figure was determined (table 4-VIII). Classification accuracy was computed with the formula

$$\frac{(\text{Number of fields of crop species} \times 100 \text{ percent})}{\text{Number of fields of same color as crop species}}$$

The classification figures are virtually meaningless, however, because they reflect crop species populations to

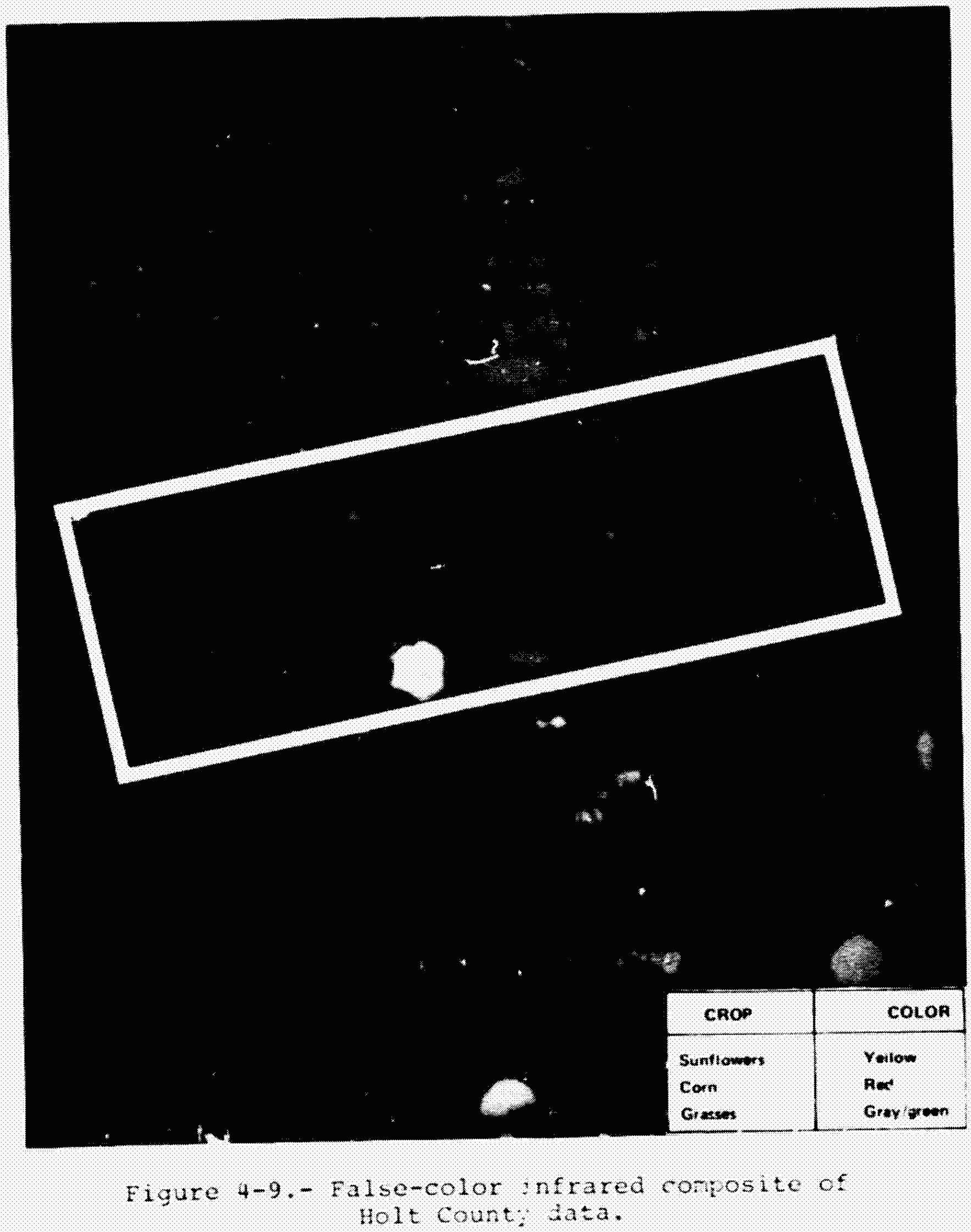

Figure 4-9.- False-color infrared composite of Holt County data.

TABLE 4-VIII.- HOLT COUNTY CROP CLASSIFICATION - COLOR IR RENDITION

Crop	Color[a]	No. of fields	Crop at color, %	Classification accuracy of crop species, %
Sunflowers	Y	1	100	100
Field corn, tasseling and immature	R1	23	70	91.5
	R2	6	18	
	R1+R2	1	3	
	R1+Y	2	6	
	R1+R3	1	3	
Popcorn, tasseling	R1	1	33	10.5
	R1+Y	1	33	
	R2+B	1	33	
Grass, 45.7 cm	C1	7	58	44.5
	C2	4	33	
	R3	1	9	
Grass, 94.5 cm	C2	2	100	22
Pasture	C2	2	100	17
Alfalfa, 61.0 cm, bloom stage	C1	2	40	18.5
	C2	2	40	
	R3	1	20	
Alfalfa, young	R3	1	50	10.5
	C	1	50	
Brome, 15.2 cm	C2	1	100	11
Brome, 76.2 cm	B1	1	100	50
Volume cover, 61.0 cm to 91.4 cm	R3	2	100	33
Grain sorghum	R3	1	50	15
	R2	1	50	
Fallow	B1	1	100	50

[a]Color code, analog color IR - R1, bright red; R2, dark red; R3, pink; Y, yellow; C1, light cyan; C2, dark cyan; B1, blue; and B, black.

a great extent, and not the uniqueness of crop-color display. For example, if half the test site was planted in grain sorghum and the other half in corn, the classification accuracies would probably be nearer 85 percent and 67 percent, respectively, which is far from the 15 percent and 91.5 percent tabulated.

As may be seen in following classification discussions, the results tend to point toward a relationship among crop, maturity stage, and the color shown on the image enhancement. However, sufficient ground truth was not available for this data set to enable a useful analysis to be made.

Conventional image interpretation was used to identify fields larger than 7.5 hectares (19 acres) from JSC and GSFC color composites. After many enhancements were viewed, the JSC color composites from the DAS were used for crop identification. The enhancements shown in figures 4-10 and 4-11 have an image scale of 1:92,565. Figure 4-10 contains ERTS band 5 (red) on the DAS green gun, band 6 (lower IR) on the red gun, and band 4 (green) on the blue gun. Figure 4-11 contains ERTS band 5 (red) on the DAS green gun, band 7 (higher IR) on the red gun, and band 4 (green) on the blue gun.

There were some bad data lines on the tape in the red band just to the south of the study area. The bad data were not on the red band film received from GSFC. For the selected scene date, table 4-IX shows the stage of maturity of crops as they appear on the ground observations and on the crop calendar.

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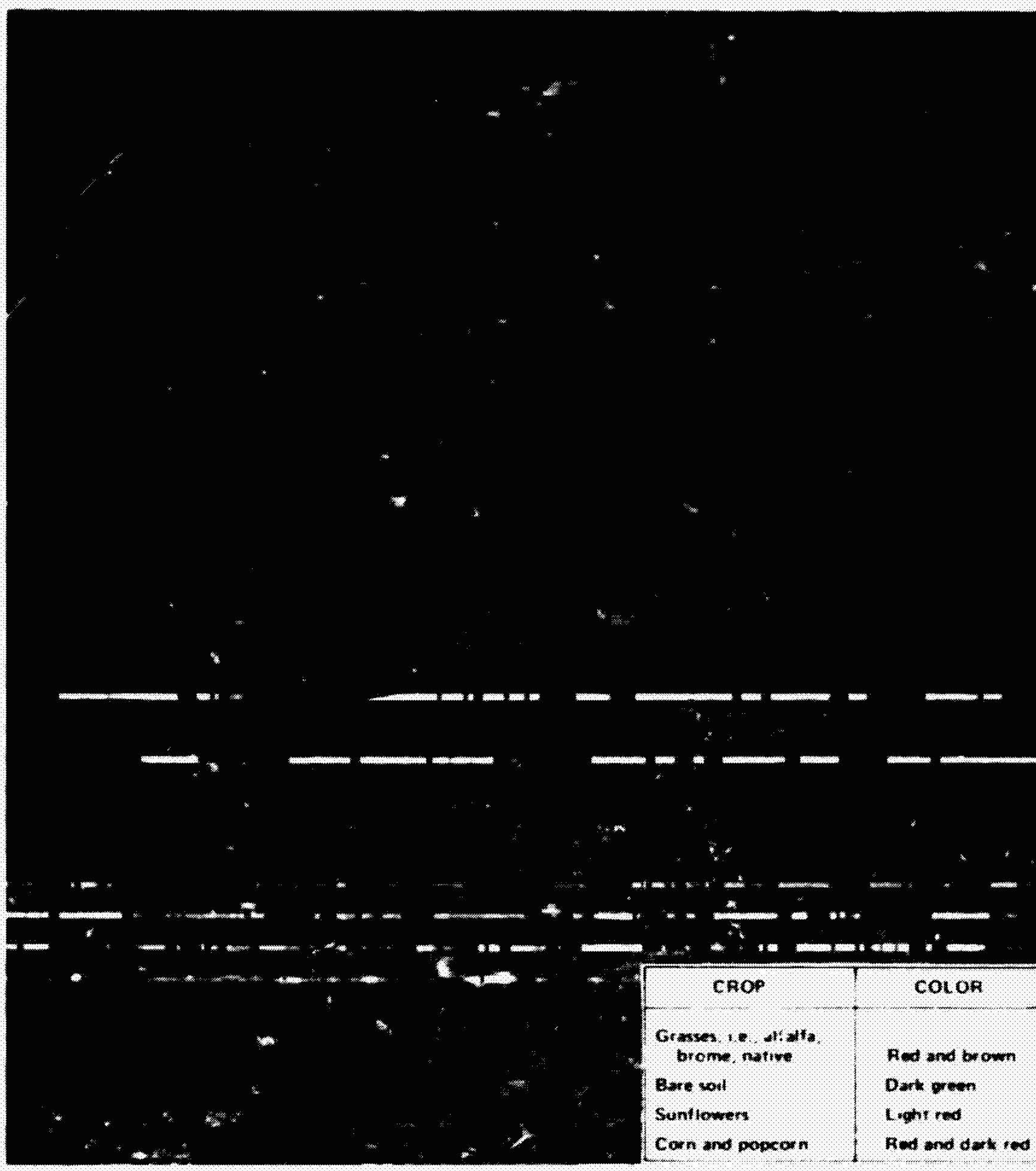

Figure 4-10.- JSC color composite of Holt County data (MSS bands 4, 5, and 6; scale 1:32,565).

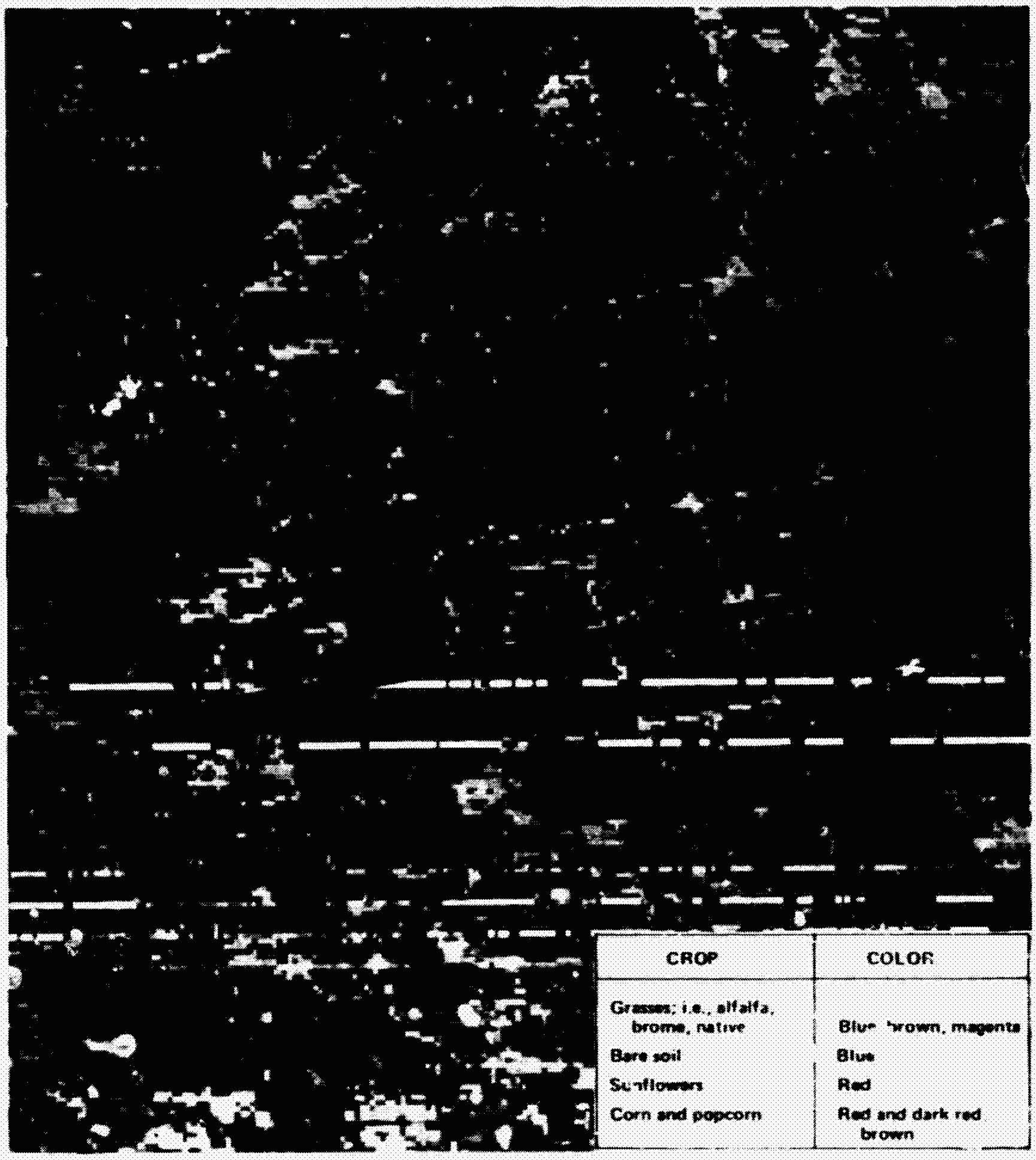

Figure 4-11.- JSC color composite of Holt County data (MSS bands 4, 5, and 7; scale 1:92,565).

TABLE 4-IX.- STAGE OF MAJOR CROPS FROM CROP CALENDARS AND FROM THE MOST CURRENT GROUND OBSERVATIONS

Crop	Crop calendar, July 30, 1972	Annual ground observations, July 28, 1972
Corn	Tassel 100% ground cover	Tasseling; starting to tassel
Alfalfa	Intermediate growth stage	Blooming
Grain sorghum	Heading 100% ground cover	--
Sunflowers	Heading 100% ground cover	Blooming

From figures 4-10 and 4-11, the colors of each training field were listed in table 4-X. The colors were grouped into four classes. Type 1 included grass, alfalfa, brome, weeds, sorghum, and haygrazer. Type 2 consisted of bare soil, type 3 of sunflowers, and type 4 of corn and popcorn.

All the large fields in the study area which were not training fields were selected as test fields. Based on its color, each test field was put in one of the four classes.

The classification results (shown in table 4-XI) were compared with the ground observations to determine accuracy. This shows that with good confidence nearly all fields in the study area can be grouped into four types.

After the study area was separated into the four types, crop identification was attempted. The information in table 4-X was used to prepare table 4-XII, which is an

TABLE 4-X.- COLORS OF TRAINING FIELDS FROM FIGURES 4-10 AND 4-11 FOR HOLT COUNTY

Crop	Test fields			Color, %	
	Section	Farm no.	Field no.	Figure 4-10	Figure 4-11
Grass	24	X 104	2	Brown 1[a], 90	Brown 1[a], 90
Alfalfa	17	K-90	6	Red 2, 90	Brown 4, 95
Sunflowers	21	A 269	7A	Red 3, 75	Red 2, 95
Bare soil	19	A 1029	4B2	Green 1, 80 Green 2	Blue 3, 80 Blue 4
Weeds	22	A 284	2A	Brown 1, 60	Brown 1, 70
Popcorn	13	A-1009	2A	Brown 1, 60 Red 1 Red 2	Brown 3, 70 Brown 4, 15 Brown 2, 15
Brome	18	070	2	Brown 2, 90	Blue 2, 95
Pasture	14	B 1005	3	Brown 2, 90	Blue 2, 90 Magenta
Corn	15	0-114	4	Red 1, 80 Red 2	Red 1, 70 Red 2, 15 Brown 2, 15
Corn	19	A-1029	4B1	Red 1, 50 Red 2, 50	Red 1, 50 Red 2, 50

[a]Intensity of brightness from darkest 1 to brightest 4.

TABLE 4-XI.- ACCURACY OF CLASS IDENTIFICATION FOR HOLT COUNTY

Class	All fields	Small fields	Large fields	Training fields	Test fields	Test fields identified	Accuracy, %
Type 1 (grasses)	104	91	14	4	10	10	100
Type 2 (bare soil)	2	0	2	1	1	1	100
Type 3 (sunflowers)	3	0	3	1	[a]2	[a]2	100
Type 4 (corn)	36	4	32	4	28	25	89

[a]Test fields were out of study area because there was only one sunflower field in study area.

TABLE 4-XII.- IMAGE INTERPRETATION KEY
FOR HOLT COUNTY CROP IDENTIFICATION

Color, intensity		Crop
Figure 4-10	Figure 4-11	
Brown [a]1	Brown 1	Grass or weeds
Red 3	Red 2	Sunflowers
Green 1	Blue 3	Bare soil
Brown 1	Brown 3	Popcorn
Brown 2	Blue 2 or blue 2 and magenta	Brome or pasture
Red 2	Brown 4	Alfalfa
Red 1 and red 2	Red 1 and red 2	Corn

[a]Intensity of brightness from darkest 1 to brightest 4.

image interpretation key for crop identification. In this table, the colors from table 4-X were grouped so that each color had a crop type on table 4-XII. All the large fields in the study area which were not training fields were selected as test fields. Based on the color, each test field was classified as a crop.

After identification, the results were compared with the ground observations to determine accuracy. Accuracy is shown in table 4-XIII. This table shows that sunflowers and bare soil can be identified with good confidence; corn, with less. The various types of grass look similar and are difficult to separate.

4.1.1.5 Butte County.- The data set for September 19, 1972, was used to produce recombined enhancements of ERTS MSS imagery. Third-generation GSFC 24-centimeter (9-1/2-in.) positives were used on both the ACVP and the MCFV.

Figure 4-12 is a false-color IR rendition produced on the ACVP. MSS 6 was projected as a red color, MSS 5 as green, and MSS 4 as blue. The resulting recombination proved to be one of the best additive color enhancements produced during this study. Various colors, saturations, and brightness are evident and the sharpness of the imagery is good.

Table 4-XIV lists the fields for which ground truth was available and the color that the field was judged to have in the subject figure. The fields used as a color reference for comparison are indicated with a superscript b in the color column. All colors were determined visually.

TABLE 4-XIII.- ACCURACY OF CROP IDENTIFICATION OF HOLT COUNTY

Crop	Number of fields					Accuracy, %
	Large fields, >7.5 ha	Training fields	Test fields	Correctly classified	Mis-classified	
Pasture	4	1	3	2	1	67
Corn	31	3	28	26	2	93
Alfalfa	2	1	1	0	1	0
Brome	2	1	1	0	1	0
Popcorn	3	1	2	0	2	0
Bare soil	2	1	1	1	0	100
Sunflowers	3	1	[a]2	2	0	100
Grass	3	1	2	2	0	100
Total	50	10	40	33	7	82

[a]Test fields were outside study area.

C-2

CROP	COLOR
Small grains (rice)	Light red, red, white
Coarse grains (corn, grain sorghum)	Dark red
Truck farm crops (sugar beets, dry beans)	Light red, pink
Hay/forage (pasture, alfalfa, Sudangrass)	Light green, light red
Orchard trees (plums, almonds, walnuts)	Brown
Fallow (bare soil, various stubbles)	Dark gray, white
Water (lake in lower right corner)	Black

Figure 4-12.- ACVP of Butte County data acquired September 19, 1972 (false-color IR enhancement of MSS bands 4, 5, and 6).

TABLE 4-XIV.- BUTTE COUNTY GROUND TRUTH VERSUS DISPLAY COLOR ON THE ACVP AND MCFV

Farm no.	Field no.	Area, hectares	Crop	Aug. '8, 1972		Sept. 19, 1972	
				Est. crop height, cm	State of maturity	Display color[a]	
						ACVP	MCFV
2167	2	2	Irrigated pasture	9.1	Mature	P1	RM
2167	3	6	Irrigated pasture	15.2	Mature	P1	RM[b]
2165	1	4	Irrigated pasture	6.1	Mature	P1	RM
2165	2	5	Irrigated pasture	15.2	Mature	P1	RM
781	1	9	Idle, fallow	0	0	G	B
2164	1	6	Idle, fallow	0	0	G	B
678	3	15	Plums	548.6	Harvested	M2[b]	MB
678	2	12	Plums	548.6	Harvested	M2	MB
1582	25	113	Rice	106.7	Nearing maturity	P1	RO
1582	4	20	Rice	?		P1	RO
751	2	17	Almonds			G	B
1688	10	12	Field corn	213.4	Green	R2	M
273	1	59	Fallow	0	0	G[b]	G[b]
623	1	51	Rice	106.7	Nearing maturity	P2[b]	O2
579	1	53	Rice	106.7	Nearing mat rity	P1	RO
579	2	39	Idle	152.4	Weeds, ripening	G	B[b]
499	1	15	Rice	106.7	Nearing maturity	P3	O2
499	2	16	Rice	106.7	Nearing maturity	P3	O2
499	3	15	Rice	106.7	Nearing maturity	P3	O2
499	4	15	Rice	106.7	Nearing maturity	P3	O2
1199	1	29	Rice	106.7	Nearing maturity	P1	RO
209	1	43	Fallow	0	0	G	YG
209	2A	62	Rice	106.7	Headed out, green	P1	RO
1199	6	263	Rice	106.7	Mature, harvesting	P3[b]	O2[b]
1199	1	209	Rice	106.7	Headed out, green	P1[b]	RO[b]

[a]ACVP display - R1, bright red; R2, dark red; P1, bright pink; P2, medium pink; P3, pink-white; W, white; B, black; G, gray (all); M1, dark magenta; and M2, light magenta. MCFV display - R, red; RO, red-orange mix; O1, yellow-orange; O2, orange; O3, dark orange; YG, yellow-green mix; M, magenta; MB, magenta-blue mix; B, blue; G, green; and RM, red-magenta mix.

[b]Field used as color standard.

TABLE 4-XIV.- BUTTE COUNTY GROUND TRUTH VERSUS DISPLAY COLOR ON THE ACVP AND MCFV - Concluded

Farm no.	Field no.	Area, hectares	Crop	Aug. 10, 1972		Sept. 19, 1972	
				Est. crop height, cm	State of maturity	Display color[a]	
						ACVP	MCFV
293	4	10	Wheat stubble fallow	0	0	G	?
293	5	9	Fallow	0	0	B	YG
293	6B	15	Sugar beets	45.7	Maturing	P2	MB[b]
293	8	8	Sugar beets	45.7	Maturing	P1	RO
293	11	13	Alfalfa	61.0	Nearing maturity	R1[b]	R[b]
946	1	34	Alfalfa	61.0	Mature, harvesting	M1	M
1582	11	85	Rice	0	Stubble	W[b]	O1[b]
1582	12	53	Fallow	0	0	B	YG
1688	1	19	Field corn	213.4	Green	R2	M
1688	7	21	Field corn	213.4	Green	R2[b]	M[b]
1688	8	23	Field corn	213.4	Green	R2	M
1688	9	10	Field corn	213.4	Green	R2	M
1688	2	28	Field corn	213.4	Green	R2	M
768	1	7	Sudangrass	30.5	Immature	P3	O3
1567	3	17	Sudangrass	30.5	Immature	P3	O3[b]
1874	1	15	Almonds	548.6	Mature	M2	MB
2159	1	16	Almonds and walnuts	365.8 609.6	Mature	W	O2
970	3	8	Wheat stubble	0	Fallow	G	B
970	4	11	Wheat stubble	0	Fallow	G	B
2155	1	5	Grain sorghum	121.9	Maturing	P1	MB
1199	7	94	Field corn	243.8	Near maturity	M1[b]	M
1199	2	77	Fallow	0	0	B[b]	YG[b]
1199	31	58	Dry beans	45.7	Starting to mature	P1	R
1199	32	20	Dry beans	45.7	Starting to mature	W	O2

[a]ACVP display - R1, bright red; R2, dark red; P1, bright pink; P2, medium pink; P3, pink-white; W, white; B, black; G, gray (all); M1, dark magenta; and M2, light magenta. MCFV display - R, red; RO, red-orange mix; O1, yellow-orange; O2, orange; O3, dark orange; YG, yellow-green mix; M, magenta; MB, magenta-blue mix; B, blue; G, green; and RM, red-magenta mix.

[b]Field used as color standard.

The identification of agricultural and nonagricultural land follows basically the same reasoning that has been used with the other study sites. Land devoted to agriculture was found to be identifiable to a high degree of accuracy by the regular geometric shapes of such areas. Cities, rivers, and barren land showed as irregular features in the subject figure very reliably when compared to ground-truth photography. In addition, water was identified by its black to bluish-black color as seen in lower right-hand corner of the subject figure. Barren land was usually found to be irregularly shaped and almost white or greenish-blue. Either color signifies a comparatively low IR reflectance and hence the presence of very little vegetation.

Cropland was identified readily in the study site by shape, because fields generally have boundaries composed of straight or gently curved lines. The spectral response was also a reliable clue. No problem was experienced in identifying cropland in the study area with these criteria. Accuracy was never 100 percent, but was within a few percent, due primarily to the limited spatial resolution of the data.

Black-and-white negative and positive transparencies were examined at various magnifications and minimum detectable features were noted. A comparison was made with the ACVP color IR rendition, and it was found that the enhancement was equal in resolution to any of the single bands.

Refer to figure 4-12 of the classification section. The smallest light-colored field detectable is about 2 hectares (5 acres), rectangular, and bordered by contrasting fields of gray, red, pink, and black. One field of 4 hectares (9 acres) could be located without difficulty and probably represents a lower limit for usable field size. The field is light and in an area of moderate-to-low contrast. A dark red field of 5 hectares (13 acres) was located on the south border of the 4-hectare (9-acre) field and is near the limit of useful size for other than detection. The individual orchard fields which are of the same contrast and located in the same general area could not be distinguished. The largest of these fields is about 14 hectares (36 acres).

A divided highway is visible over most of its length, although it becomes difficult to locate as it passes through an area of low-contrast orchard fields. A two-lane paved highway is detectable, but only because it forms a boundary for a number of contrasting fields. A canal about 30 meters (100 ft) wide is detectable as it passes through dark fallow fields, but is visible elsewhere only because it defines field borders. A dark strip of trees only 23 meters (75 ft) wide can be seen without too much difficulty. Several indications of homesteads are visible as unresolved white spots, but only in areas where white contrasts well. A long rectangular field about 64 meters (250 ft) wide was easily seen and could probably be recognized as a field if the width was perhaps 40 meters (150 ft) or greater.

Contrast is an important factor in determining the detectability of a surface feature. White areas were found to contrast well with other colors most often, while light pink or magenta contrasted most poorly. Dark-colored fields were not quite as easy to detect as white, and generally showed to be smaller than the ground truth indicated. A final comparison of the color IR rendition was made with black-and-white photographs, but the color IR was still found to be preferable.

The crops within the study area may be divided into several types based partly upon botanical characteristics and partly upon the use of the crop. The types which were selected were small grains (rice), coarse grains (field corn, grain sorghum), truck farm crops (sugar beets, dry beans), hay/forage (pasture, alfalfa, Sudangrass), orchard trees (plums, almonds, walnuts), and fallow (bare soil, various stubbles). These types are listed on figure 4-12, with the colors given in the next-to-last column of table 4-XIV in order to determine if a type-color relationship exists for this figure.

A satisfactory identification of type by color has not been achieved. Considerable confusion is evident among the first four types, while the last two, orchard trees and fallow, show some similarity. It appears as though an IR/non-IR reflectance correlation has resulted instead. The orchard trees are listed as mature or harvested and the leaves are either dropping, changing color with the late date in the season, or the ratio of tree leaf area to bare soil area is small. The tabulated data may also be arranged to determine if a unique color-crop species relationship exists. The results were as shown in the following table.

Color displayed in figure 4-12	Crop species or field condition
R1	Alfalfa, near maturity
R2	Field corn
P1	Pasture, rice, sugar beets, grain sorghum, dry beans
P2	Rice, sugar beets
P3	Rice, Sudangrass
W	Rice stubble, almonds, wheat stubble
B	Idle-fallow
G	Idle-fallow, almonds, wheat stubble
M1	Field corn, alfalfa harvested
M2	Plums, almonds

Only R1, R2, and B indicate one crop species or field condition. P1, P2, and P3 include several species, with possibly only one factor in common — all the crops are growing, have not been harvested, but are nearing maturity. Harvested fields, dormant trees, and fallow are included in W and G; these all have low IR reflectivity. M1 and M2 include field corn, which is probably near the end of its growth, harvested alfalfa, and dormant plum and almond trees. These all have moderate-to-low IR reflectivity in common.

Crop classification by color has not been achieved, and it is therefore needless to compute accuracies. The analysis points out once again that the color which a crop exhibits in a false-color IR display is indicative of its vigor, maturity, or condition. Thus, a field such as rice which has been recently planted may follow the color cycle of B (planted), P3 (young growth), P2 (immature), P1 (near maturity), P3 (being harvested), W (rice stubble), G (idle-fallow, old stubble). Assuming that the crop type is known, this information should prove to be valuable. In addition, it has been shown that this may be achieved using ERTS imagery. The smallest individual field used in this analysis was 4.5 hectares (11 acres) and of high contrast.

A density-sliced color-coded enhancement made on the MCFV for the subject data set is shown in figure 4-13. The MSS bands 5 and 6 were set for optimum display and combined to produce the composite enhancement. Color mixes and various intensities of the same color appearing in the final display are due to the addition of information from the two bands. Since a different color key usually is used for each band, color mixes are produced. Some overlapping of colors occurs for the smallest fields and an accurate color is not produced for that field. This may be seen for fields of perhaps 10 hectares (25 acres) or less.

The color of each field as displayed in figure 4-13 is also listed in table 4-XIV. The color code appears at the bottom of the table with each color reference field indicated. One training field each was used to devise color codes for rice, corn, alfalfa, bare soil, and orchard trees.

CROP	COLOR
Small grains (rice)	Orange, red, orange mix
Coarse grains (corn, grain sorghum)	Magenta, blue
Truck farm crops (sugar beets, dry beans)	Magenta mixture, red, orange
Hay/forage (pasture, alfalfa, Sudangrass)	Blue, magenta mix, dark orange
Orchard trees (plums, almonds, walnuts)	Blue (upper left)
Fallow (bare soil, various stubbles)	Green, yellow/green

Figure 4-13.- Butte County MCFV enhancement of MSS bands 5 and 6 (conventional image interpretation of September 19, 1972, data).

The following table was prepared using table 4-XIV data and the crop types used in the previous discussion with the color-IR rendition.

Crop type	Color displayed
Small grains	RO, O2
Coarse grain	M, MB
Truck farm crops	MB, RO, R, O2
Hay/forage	RM, R, M, O3
Orchard trees	B, MB, O2
Fallow	B, YG

There is obviously a great amount of overlap between the various crop types and displayed colors. Perhaps the only type that can be identified without considerable ambiguity is fallow. The conclusion was that either the display was set up poorly, a crop type-color relationship does not exist, or that the division into crop types has been improperly devised.

The data may also be arranged to determine if a crop species-color relationship was achieved (Level IV). The following table was prepared to determine this and classification accuracies were computed.

Crop classification may be computed by

$$\frac{(\text{Number of fields of crop}) \times (100 \text{ percent})}{\text{Number of fields displaying the same color as crop}}$$

The crop classification accuracies shown in table 4-XV were calculated using the above equation.

TABLE 4-XV.- CROP CLASSIFICATION ACCURACIES

Crop species	Classification accuracy, %	Colors	No. of fields
Rice	80	RO, O2	12
Rice, stubble	100	O1	1
Idle-fallow	67	B, G, YG	8
Field corn	78	M	7
Alfalfa, maturing	50	R	1
Alfalfa, harvested	11	M	1
Sugar beets	18	MB, RO	2
Sudangrass	100	O3	2
Dry beans	20	O2	2
Grain sorghum	11	M	1
Wheat stubble	30	B	2
Almonds	16	O2, B	3
Pasture	100	RM	4
Plums	50	MB	2

Many of the percentages appear quite low. However, most of the poorer classifications were based on a sample of only one or two fields and should not be considered as necessarily valid. Rice stubble and wheat stubble should be placed into the idle-fallow group, since the fields were not planted and were similar to the contents of other fallow fields. This increases the accuracy of classification for idle-fallow to 75 percent, and the 30 percent figure for wheat stubble is eliminated. Other groupings could probably be made which would improve the results, as well as give more useful crop categories.

As shown earlier in this report, the maturity of the various crop species was generally the major factor determining the color of their display; for example, rice may be followed through its growth cycle as follows:

Crop	Color displayed
Fallow field, planted with rice	Yellow-green mix
Rice nearing maturity, good growth	Red-orange mix
Mature rice, good growth, maximum ground cover	Red
Rice at harvest stage	Orange 2, 3
Rice stubble, fresh	Orange 1
Old rice stubble, plowed under, wet soil	Yellow-green mix

Other crops show a similar pattern, but perhaps with some difference in colors at each stage. For example, corn and alfalfa would appear magenta at some stage in their growth. This might be attributable to the mix of soil and plant spectral reflectivity, the percentage of ground cover, general health of the crop, or numerous other factors. Much more data sampled at various points in the growth cycle for each crop type will be needed before a dependable interpretation can be made.

A temporal enhancement is shown in figure 4-14. To produce the enhancement, MSS band 6 taken on September 19, 1972, was projected as red, and MSS band 6 taken on October 6, 1972, was projected as green. The print shown in figure 4-14 is not as sharp as the original image formed on the ACVP screen

[See table 4-XVI for color code.]

Figure 4-14.- Butte County temporal enhancement of MSS band 6.

TABLE 4-XVI.- BUTTE COUNTY DATA FOR TEMPORAL ENHANCEMENT OF MSS BAND 6

[Figure 4-14 field color]

Field	Crop	Field color in figure	Crop condition Sept. 19, 1972	Crop condition Oct. 6, 1972
1199-6	Rice	Red/brown	107 cm high, harvesting	Harvested, burned out
1582-11	Rice	Red/brown	Harvested, stubble	Harvested, tillage
293-8	Sugar beets	Red/brown	46 cm high, maturing	Harvested, bare soil
293-6a/6b	Sugar beets	Red/brown	46 cm high, maturing	Harvested, bare soil
768-1	Sudangrass	Red/brown	30 cm high, immature	Harvested, tillage
1567-3	Sudangrass	Red/brown	30 cm high, immature	Harvested, tillage
623-1	Rice	Red	107 cm high, near maturity	Harvested, tillage
293-11	Alfalfa	Red	61 cm high, near maturity	30 cm high
1199-7	Field corn	Brown	244 cm high, near maturity	Harvested, tillage
946-1	Alfalfa	Light blue/ green	61 cm high, harvesting	6 cm high, cutting removed
499-1,2 3,4	Rice	White, light yellow	107 cm high, near maturity	30 cm high, straw, harvested
1199-1	Rice	White	107 cm high, headed, green	107 cm high, mature
209-2A	Rice	White	107 cm high, headed, green	107 cm high, mature
1199-31	Dry beans	White	46 cm high, near maturity	61 cm high, near maturity

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because of losses and changes in color balance in subsequent printing.

A cursory examination of the enhancement did not reveal that a crop classification by color had been achieved. However, examination of ground-truth data for the two combined dates indicates that the colors may correspond to certain crop changes that occurred during the 18 days between photographs. Since the near-IR band from both dates was used, the colors represent changes in the amount of IR reflectivity. This may be because of differences in the amount of green vegetation present or from the spectral reflectivity of other ground cover. Table 4-XVI was prepared from ground-truth data for those fields which indicated a field condition change by their display color.

The red/brown color generally corresponds to crops which were harvested during the 18 days between data collection. The first ricefield had been harvested and the stubble burned over. The second ricefield indicated tillage remaining on the ground; but, judging from the very low reflectivity on the second date, the stubble must also have been burned. Red also is shown for harvested sugar beets and Sudangrass.

One ricefield which was harvested between data collection dates shows as red; the stubble in this case had apparently not been burned. A field of alfalfa also appears red. This indicates a higher IR reflectivity on the first date by the excess red needed to produce an orange color when mixed with green from the second date. The ground truth (table 4-XIV) shows that the alfalfa was indeed more luxuriant on the earlier date.

A blue/green color in figure 4-14 should indicate a high IR reflectivity on the second date with little on the first. White fields in each case represented crops which were green on both dates. Similarly, light brown to dark brown indicated that little change occurred in those fields between the two dates, with very low IR reflectivity in general. This proved to be the case by examining additional ground-truth data.

This brief analysis showed that if a crop species was known, its stage of maturity, including harvest, could be inferred from temporal data. By selecting temporal sets from other dates in the growing season, other growth factors might well be discerned. In addition, it was determined that imagery from two consecutive ERTS data sets that were 18 days apart could be registered without difficulty. Temporal enhancements were generated as easily as those for single-date data sets.

Figure 4-15 is a temporal enhancement produced by combining on the ACVP the October 6, 1972, MSS band 5 as a blue color and MSS band 7 as green, with the MSS band 7 for October 24, 1972, as a red color. Using this setup and based upon previous studies, the following general statements were ascertained.

1. Any color in the figure which has blue as a component should indicate a field which has a relatively high soil reflectivity and low IR responses. Cyan, blue, and light purple are included.

[See table 4-XVII for color code.]

Figure 4-15.- Butte County ACVP enhancement of MSS bands 5 and 7.

TABLE 4-XVII.- BUTTE COUNTY DATA FOR ACVP ENHANCEMENT OF MSS BANDS 5 AND 7

[Figure 4-15 field color]

Field	Crop	Color in figure	Crop condition Oct. 6, 1972	Crop condition Oct. 24, 1972
1199-7	Field corn	Blue, light purple	Harvested, tillage	Harvested, tillage
623-1	Rice	Light purple	Harvested, tillage	Partial tillage
1199-31	Dry beans	Yellow, green at north end	61 cm high, near maturity	61 cm high, partially cut at north end
1199-1	Rice	Light yellow	107 cm high, mature	107 cm high, partially harvested
209-2A	Rice	Light yellow	107 cm high, mature	107 cm high
2167-2,3	Irrigated pasture	Yellow	6 cm high, mature	3 cm high, mature
2165-2,1				
1688-1	Field corn	Spotted yellow	244 cm high, green drowned spots	244 cm high, maturing drowned spots
1688-7	Field corn	Dark yellow	244 cm high, green	244 cm high, green
946-1	Alfalfa	Orange	6 cm high, cutting, just removed	18 cm high
623-11	Alfalfa	Orange	30 cm high	37 cm high
1199-6	Rice	Dark red	Harvested, burned over	Harvested, burned over
1199-2	Fallow	Dark purple	Bare soil	Plowed bare soil

2. Any color with green as a component should indicate a field with high IR reflectivity on the first date. This primarily includes green and cyan. Yellow signifies high IR response on both dates.

3. Any color with red as a component should indicate a field with high IR reflectivity on the second date. This primarily includes red, magenta, or purple.

4. Very dark colors should represent harvested or fallow fields of low reflectance. This could be due to burning, wet soil, or freshly plowed damp soil.

Table 4-XVII was prepared to test the above statements. As in the previous temporal analysis, crop identification was not attempted because this did not appear to have been achieved.

The first two fields in table 4-XVII apply to statement 1, and according to the ground-truth data both fields had a higher soil reflectivity than did vegetation. The first field, corn, had a blue strip along the eastern half, which probably indicates that the field was half plowed under on the first date and completely plowed under on the second date.

The only field showing any green at all was the north end of a field of dry beans. According to ground-truth data, this area was harvested by the second date, which accounts for the higher IR reflectivity on the first date. (This is in agreement with statement 2.)

The fields ranging from light yellow to orange were indicative of a good vegetation response on both dates; this is supported by ground-truth data. Drowned spots in one cornfield were discernible as a spotted effect. Ricefield 1199-1 can be seen as partially harvested in the northern portion on the original enhancement. The only red field for which ground truth was available did not indicate vegetation for either date. However, the magenta-colored areas to the east of the test site were grasslands with a component of soil reflectivity on the first date, and increasing grass ground cover on the second date. This ground-truth information was taken from color-IR enhancements and supports statement 3. Statement 4 was true in each case.

It is evident that a logic may be developed in which the condition of a field may be inferred through the use of a temporal enhancement and a general knowledge of the spectral reflectance characteristics of soil and vegetation. Also, crop classification by temporal additive color techniques appears improbable using ERTS data. No doubt cases will arise when this will be achieved, but this is unlikely on a regular basis.

During this study an effort was made to determine the effects of establishing training data at one location (Imperial County) and using this training data for classification at another location (Butte County). No attempt was made to apply any corrections to the raw data. An overall classification performance of 40 percent was obtained (table 4-XVIII). This is not considered good; however, upon closer inspection bare soil had a classification accuracy of 86 percent and alfalfa had a classification accuracy of

TABLE 4-XVIII.- RESULTS OF SIGNATURE EXTENSION FROM IMPERIAL COUNTY TO BUTTE COUNTY, CALIFORNIA

Group	No. of samples	% Correct	Number of samples classified into -									
			Carrots	Bsoil1	Bsoil2	Beets	Alf	Aspara	Cotton	Sudgrs	Sorg	Melons
Test field performance												
Bsoil1	40	0.0	0	0	38	0	0	0	2	0	0	0
Bsoil1	21	0.0	0	0	16	1	0	0	3	1	0	0
Bsoil1	56	0.0	0	0	47	2	0	6	1	0	0	0
Bsoil2	40	95.0	0	0	38	0	0	0	2	0	0	0
Bsoil2	21	76.2	0	0	16	1	0	0	3	1	0	0
Bsoil2	56	83.9	0	0	47	2	0	6	1	0	0	0
Beets	20	0.0	0	0	0	0	9	6	0	0	1	4
Alfalfa	25	100.0	0	0	0	0	25	0	0	0	0	0
Alfalfa	16	25.0	0	0	0	0	4	0	5	0	0	7
Sudangrass	9	0.0	0	0	0	0	0	3	0	0	1	5
Sorghum	16	0.0	0	0	0	0	2	5	0	0	0	9
Totals	320		0	0	202	6	40	26	17	2	2	25
Test class performance												
Bsoil1	117	0.0	0	0	101	3	0	6	6	1	0	0
Bsoil2	117	86.3	0	0	101	3	0	6	6	1	0	0
Beets	20	0.0	0	0	0	0	9	6	0	0	1	4
Alfalfa	41	70.7	0	0	0	0	29	0	5	0	0	7
Sudangrass	9	0.0	0	0	0	0	0	3	0	0	1	5
Sorghum	16	0.0	0	0	0	0	2	5	0	0	0	9
Totals	320		0	0	202	6	40	26	17	2	2	25

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70 percent. Beets, alfalfa, Sudangrass, and sorghum had classification accuracies of zero.

4.1.1.6 Worth County.- The September 8, 1972, ERTS-1 MSS data selected for analysis were the earliest data set available in which the study area was sufficiently clear of clouds. These data were not optimum because it was late in the season and many of the crops were already at the mature or harvest stage.

Approximately 30 percent of the 19-square-kilometer (12-sq.-mi.) study area was wooded. The cultivated fields in the site were generally small, ranging in size from less than 0.4 hectare (1 acre) to 40 hectares (100 acres). The majority of the fields were less than 12 hectares (30 acres). Field boundaries followed natural contours, woods, and drainage patterns, which gave most of the fields a nonrectangular shape. Worth County was included in the analysis primarily because of the challenge presented by these small and irregularly shaped fields.

Analysis of the small irregularly shaped fields was attempted by producing false-color IR renditions on the MCFV. The results were extremely poor (fig. 4-16) when compared with the ground-truth data in figure 3-15.

A comparison of figure 4-16 and figure 4-27, page 4-87, shows irregular gray, pink, and white fields representing the color range of agricultural features. Native trees are dark red. The smallest gray field which could be located was 6 hectares (14 acres) of peanuts surrounded by contrasting colors. The minimum detectable gray field area was

Figure 4-16.- Worth County MCFV false-color IR rendition of MSS bands 4, 5, and 7.

estimated to be half of this value. The smallest pink field located was 5 hectares (11 acres) of corn and was well contrasted with neighboring fields. Approximately 8 hectares (20 acres) were required for detection in areas of poor contrast. The minimum detectable pink areas were estimated to be half of these values. No white fields of small size were available, but from the appearance of the larger white fields about 4 hectares (10 acres) were estimated as usable and perhaps 2 hectares (5 acres) detectable. Native trees which were surrounded by light-colored fields were found to be usable to perhaps 4 hectares (8 acres) and detectable to 1 or 2 hectares (3 or 4 acres). Areas with heavy tree growth appeared mostly homogeneous and showed almost no detail, except for contrasting crops which were interspersed among the trees in some areas. Water ponds, which show as dark spots, were detectable as small as 1 hectare (2 acres). Ponds twice this size were easily identifiable. Small towns and highways were undetectable, except in one or two locations where a two-lane paved highway bisected light-colored fields. Compared to other test sites, Worth County imagery was average, although the small fields tended to deemphasize actual image quality. Further analysis of the individual fields and crop types or species was not attempted using conventional image interpretation.

4.1.2 Area Measurement

Area measurement was attempted on four test areas in this analysis. The methods of analysis were explained in section 3.2.4.

The primary source of error in area measurement was thought to be misinterpretation of field boundaries.

Field boundaries could not be delineated correctly, especially if the fields were small and very narrow. In addition, poor contrast between fields contributed to poor boundary definition and to the blooming effect making brighter fields appear larger than the darker fields. A second source was the instrument scale factor used to convert measurements to hectares. A third source of error was the measurement error introduced by the operator. The standard deviation of the three measurements from the mean of the measured areas gives an indication of the size of this error. Figure 4-17 shows that measurement error depends primarily on the size of the area measured at image scale. If the overlay was enlarged, this error would decrease. Of course, with any image there is a practical limit to enlargement. The computation of area measurement was based on this formula:

$$\text{Area measurement error} = \frac{\text{Measured acreage} - \text{ASCS acreage}}{\text{ASCS acreage}}$$

4.1.2.1. Hill County.- The fields selected for area measurement in Hill County are shown in figure 4-18. Field A was used as a test field to improve the scale calibration of the data quantizer. Because of the lack of IR (vegetation) response and the predominance of fallow soil and harvested crops, the overall contrast of the Hill County data was extremely poor. Great difficulty was encountered when definition of field boundaries was attempted; therefore, only a limited number were measured. Area measurements were made by a visual estimation of field borders during each perimeter trace and from an overlay on which field boundaries were traced with a fine ink pen. The former method was found to provide better data because the operator had the opportunity to determine the borders more than once and obtain an average.

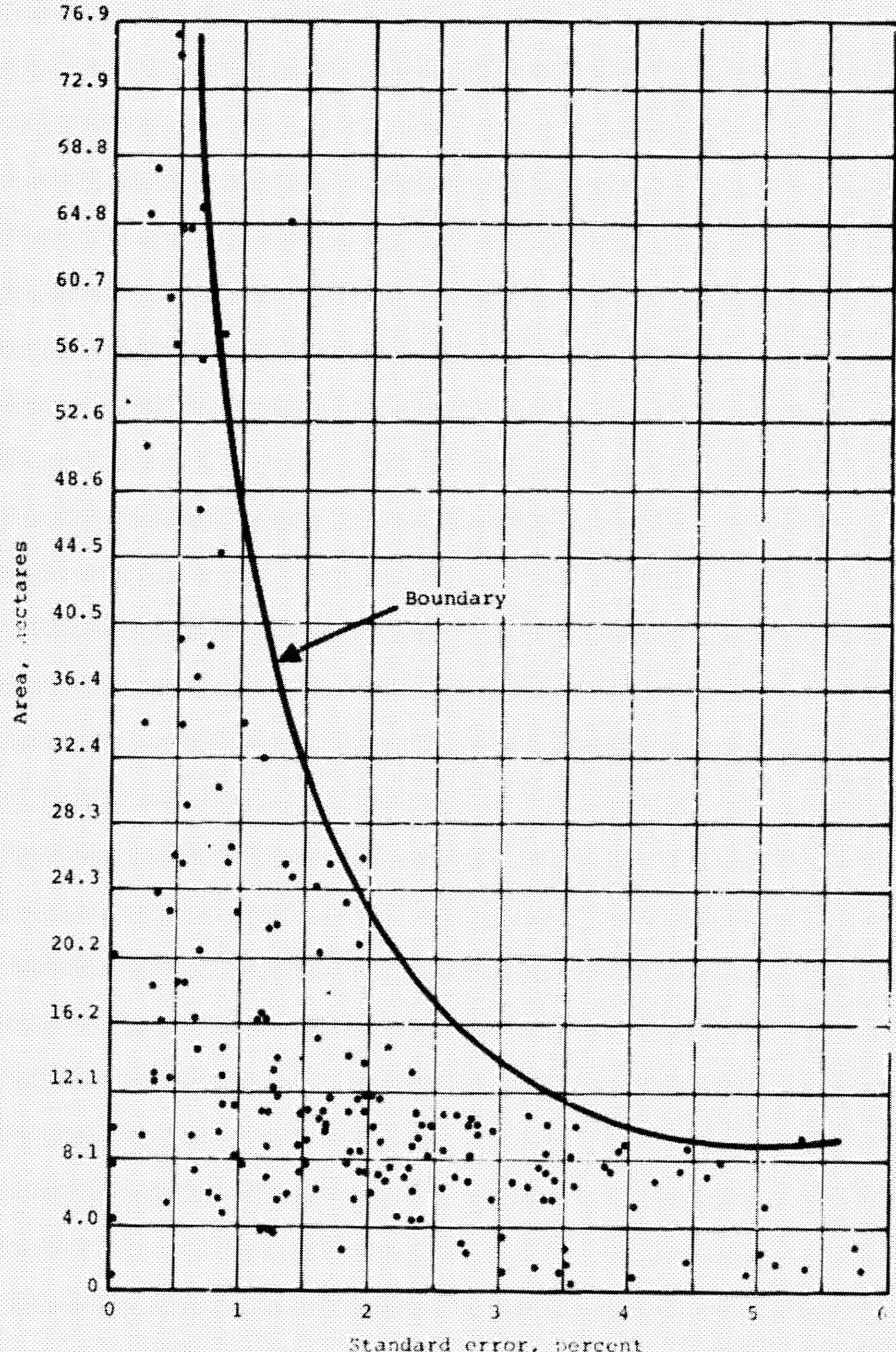

Figure 4-17.- Standard deviation for Hill County.

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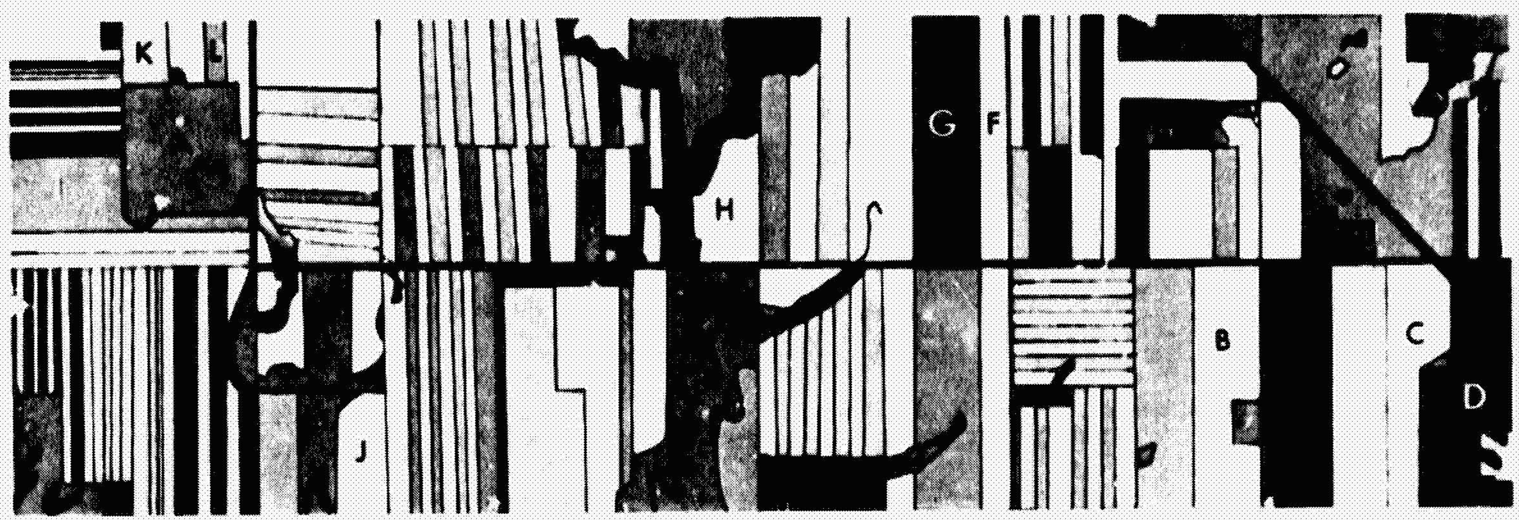

Figure 4-18.- Hill County area measurement ground-truth map with letters designating fields.

Results of the area measurements are shown in table 4-XIX. Analysis comments are as follows.

1. Hill County exemplifies the need to use a data set obtained at the proper date. The data used in this analysis were taken after the growing season, and virtually all fields were fallow, harvested, or so mature that little IR reflectance was available. The long, narrow fields characteristic of this study were difficult to measure accurately in any case, and lack of contrast between fields complicated the problem considerably.

2. Several well-defined fields showed errors of 6 percent or less. They all ran basically in a north-south direction and were either dark or surrounded by dark fields.

3. No fields alined in an east-west direction were measured because they were not resolvable.

4. As an error analysis, errors found in fields F and J were probably attributable to inclusion of area from similar adjacent fields. Field F apparently includes another field which would reduce the error from +20.1 percent to -3.2 percent. Field J must include about half of field N18-1. If so, the error is reduced from +20.6 percent to +1.4 percent. Field H error occurred because of the difficulty in separating the fallow in H from the sod along the southern border. Operators familiar with the scene probably would not make this error. The error in field I was caused by the deliberate exclusion of about 8 hectares (20 acres) which lie below field A but which cannot be distinguished. This error

TABLE 4-XIX.- AREA MEASUREMENT OF HILL COUNTY, MONTANA, AUGUST 7, 1972

Field	Description	Measured area, hectares	Actual area, hectares	Error, ±%
A[a]	Sod; dark field; borders well defined compared to all other fields.	68.7	68.0	+0.7
B	Summer fallow and sod; dark; borders poorly defined.	71.2	67.3	+6.0
C	Summer fallow; dark; eastern border difficult, other borders well defined.	46.7	47.0	-0.7
D	Spring wheat; average field brightness; borders difficult.	49.5	51.4	-3.9
E	Crested wheat grass and sod; dark field; one poor border.	42.0	38.4	+8.7
F	Summer fallow; dark; long narrow field; borders moderately defined.	40.3	33.6	+20.1
G	Spring wheat; average field brightness; borders estimated without too much difficulty.	65.5	69.6	-5.9
H	Summer fallow; dark; adjacent to dark sod area; poor southern border.	27.6	33.2	-16.8
I	Winter wheat; moderately bright field; area under field A not definable or included in area measurement.	48.1	57.9	-16.8
J	Summer fallow; dark; adjacent to dark sod area; difficult borders.	28.3	23.5	+20.6
K	Barley; moderate brightness; small field with dark adjacent fields.	15.5	12.3	+28.0
L	Summer fallow; moderate brightness; small field with relatively good borders.	8.5	9.3	-8.6
	Total	513.0	513.0	

[a]Used to calibrate image scale (1:130,000).

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would then decrease from -16.8 percent to -2 or -3 percent. The only remaining high error, field K, was apparently due to the inclusion of area of an adjacent field on the western border.

5. While long, narrow fields such as those in Hill County make good resolution targets, they were not generally suitable for individual area measurement. Field F, the narrowest field measured for area in this study, was approximately 220 meters (700 ft) wide.

4.1.2.2. Imperial County.- The fields selected for area measurement are shown in figure 4-19. Field H was used to evaluate instrument calibration since the field is about average in size and contrast and since its borders are relatively well defined. All measurements were carried out on imagery generated on the ACVP.

The results of the area measurements are shown in table 4-XX. An analysis of these measurements yielded these results.

1. Area measurements can be made from ERTS imagery of fields as small as 7 hectares (16 acres). The error in these measurements averages around ±3 to ±4 percent for fields with moderate to good border definition; however, poor border definition and other factors may cause a significant error increase. Some of these factors are discussed in the succeeding statements.

2. Fields with a strong vegetation response either tend to blur together and obscure individual borders or diffuse into adjacent fields, producing false field boundaries. For fields of 20 hectares (50 acres) or less, the errors may be

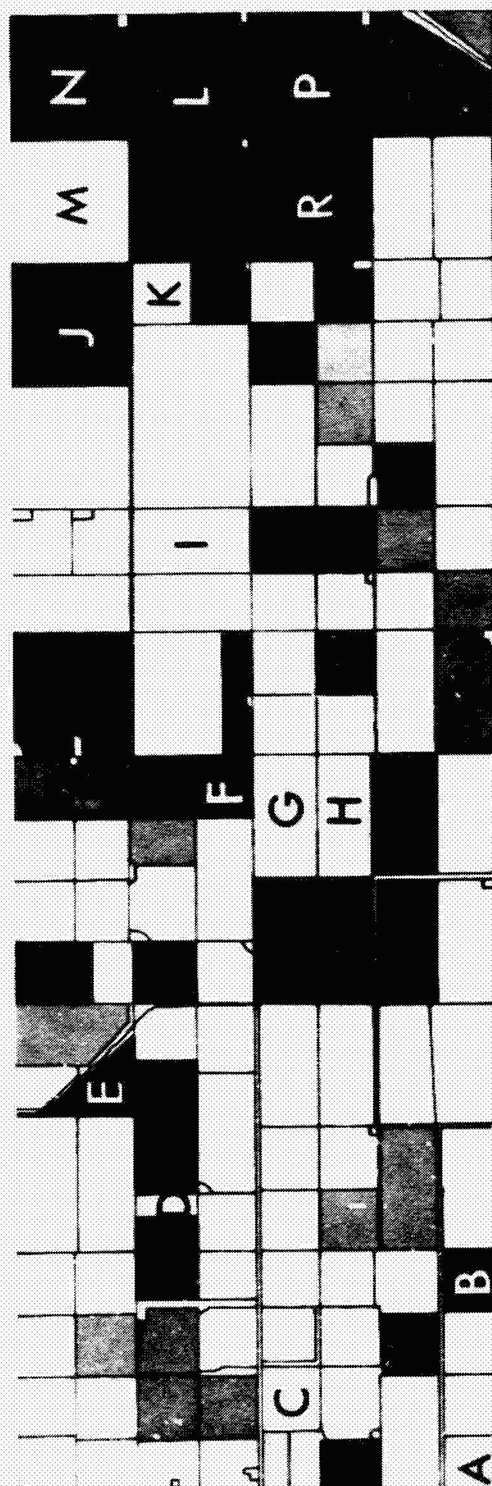

Figure 4-19.- Area measurement of Imperial County.

TABLE 4-XX.- FIELD AREA MEASUREMENTS OF IMPERIAL COUNTY, CALIFORNIA

Field designation	Description	Farm/field number	Measured area, hectares	Actual area, hectares	Error, %	Remarks
A	Small square field with strong vegetation response; two good borders and two low-contrast borders.	5/A142-6	13.2	13.7	-3.3	Alfalfa; good growth and good border on two sides.
B	Small square field with moderate vegetation; strong vegetation response on two borders; low contrast on two borders.	19/A160-1	13.1	15.1	-13.6	Melons; poor border on three sides.
C	Small square field with strong vegetation response; good borders on three sides.	441/A270-1	15.9	14.9	+6.5	Alfalfa; good growth and borders.
D	Very small rectangular white field; two borders poorly defined.	396/A436-4	6.07	6.3	-3.8	Bare soil; poor western border.
E	Triangular field with strong vegetation; good borders.	349/C511-4	20.4	19.3	+6.3	Alfalfa; good growth and borders.
F	Small square field with moderate vegetation; good border on two sides; poor border on two sides.	587/C6-13	4.8	14.2	-32.1	Melons; poor northern border.
G	Rectangular moderate-sized field with strong vegetation response and good borders.	587/A44-11	29.6	28.3	+4.3	Alfalfa(?); good growth.
H[a]	Rectangular moderate-sized field of bare soil; good borders.	587/A64-1	29.2	29.6	-1.2	Bare soil; good borders.
I	Rectangular moderate-sized field of low vegetation response; good borders.	1404/C515-4	28.1	27.2	+3.3	Alfalfa; weak growth and good borders.
J[a]	Large square fields of bare soil; various border contrasts.	1553/C545-1	59.3	60.2	-1.4	Bare soil; good borders.
K	Small square fields of low vegetation response; various border contrasts.	745/C304-1	14.7	14.3	+3.4	Light vegetation; difficult borders.
L	Large square field of moderate vegetation response; good border.	1136/C308-3	57.2	58.5	-2.1	Asparagus; good border.
M+N	Large square fields of bare soil; various border contrasts.	877/C342-1 877/C152-1	181.1	177.6	+1.2	Bare soil; good border.
S	Rectangular moderate-sized field of low vegetation response; various border contrasts.	102/C65-1	31.2	31.3	+0.1	Carrots; good [illegible] moderate bu[illegible]
P+R	Large square fields of moderate vegetation response; moderate to poor borders.	1136/C328-1 A263-1 A292-2	180.9	178.3	+1.4	Asparagus, total; good borders.

[a] [illegible]d for image scale calibration; scale 1:130,000.

as high as 6.5 percent. This effect diminishes as field size increases and is surpassed by other errors for fields larger than 61 hectares (150 acres).

3. The shape of the field does not appreciably influence the accuracy of the measurement if satisfactory border definition is present.

4. High- or low-contrast field borders should be avoided because each border introduces significantly higher errors than those of moderate contrast. High contrast, which causes the image to spread, may be represented by a strong vegetation response adjacent to bare, or nearly bare, soil. White soils adjacent to dark or wet soils are also high contrast. Low contrast, which produces poorly defined borders, usually exists between crops of similar growth, especially if luxuriant, or between fields of bare soil.

5. Although not shown in the presented data, it was found that a false-color IR rendition offered the greatest advantage for use in delineating field borders and thereby for more accurate area measurements.

6. System-corrected imagery is adequate for use in the measurement of areas of the sizes encountered by this study. How far the results may be extrapolated is unknown. It is felt, however, that higher resolution imagery would be considerably useful in delineating field borders and increasing accuracy and repeatability.

4.1.2.3 Holt County.- The fields selected for area measurement are shown in figure 4-20. The test site is dominated by corn crops and circular fields with only a scattering of other agricultural features. Field selection

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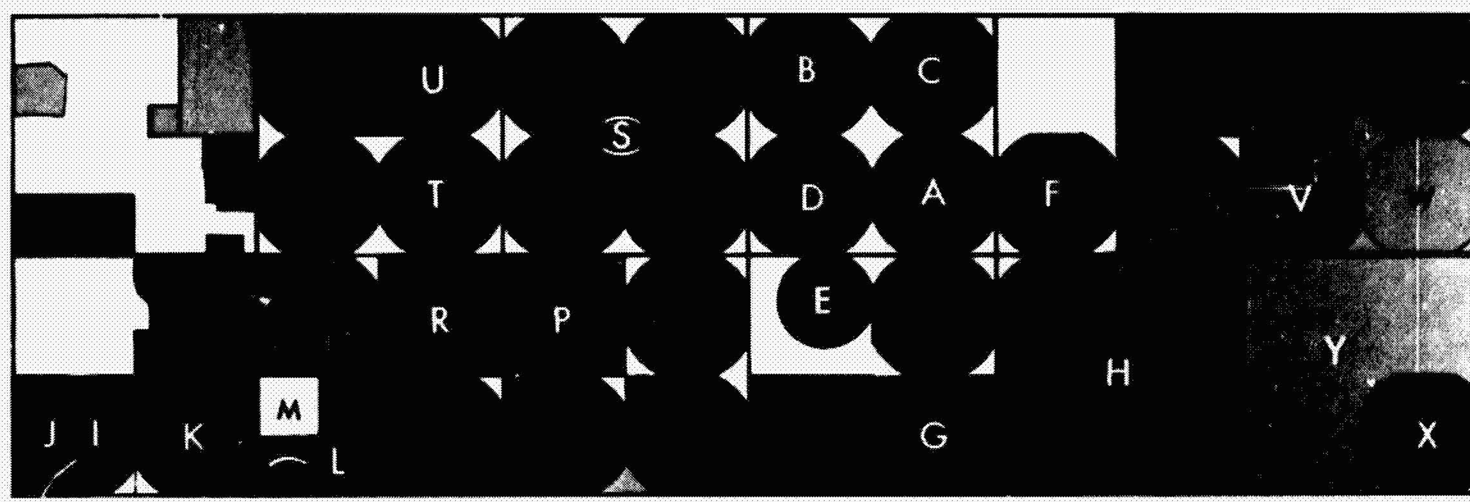

Figure 4-20.- Holt County fields selected for area measurement.

based on differing characteristics thus became an impractical task. Therefore, the rationale for selection consisted primarily of measuring as many fields as possible without regard to field condition.

Field	Description
A	Field corn; tasseling. Typical of all other fields of this size (53 ha, or 131 acres). High contrast between field and surrounding terrain with only moderate edge sharpness. Because most circular borders were similar, operator error could be reduced to a minimum by calibrating instrument using an average field. Field A was used for this purpose.
E	Field corn; smaller than average.
H	Grass between four adjacent fields; difficult borders.
I	Fallow; difficult borders.
M	Pasture; small field; difficult borders.
N	Sunflowers; otherwise similar to field A.
S	Field corn; tasseling. Four circular fields together. Poorly defined northern border.
Y	Grass; moderately well-defined borders.

The results of the area measurements are shown in table 4-XXI. Comments are as follows.

1. With proper instrument calibration, the accuracy of area measurements for the circular 53-hectare (130-acre)

TABLE 4-XXI.- FIELD AREA MEASUREMENT FOR HOLT COUNTY, NEBRASKA

[ERTS MSS imagery for July 29, 1972]

Field	Farm/field number	Measured area, hectares	Actual area, hectares	Error, ± %	Remarks
A[a]	O-114/4	322	324	-0.46	Field corn, tasseling
B	O-114/1	322	324	-0.46	Field corn, tasseling
C	O-114/2	324	324	+0.15	Field corn, tasseling
D	O-114/3	324	324	+0.08	Field corn, tasseling
E	A-121/2	175	222	--	Field corn, tasseling
F	O-114/5	335	324	+3.4	Field corn, tasseling
G	A-284/1A	314	321	-2.2	Field corn, tasseling
H	A-295/1C O-114/7d	57	5[illegible]	-4.6	Grass
I	A-1029/4B2	152	163	-6.8	Disked fallow
J	A-1029/4B1	167	163	+2.6	Field corn, tasseling
K	A-1029/5B	342	326	+4.9	Field corn, tasseling
L	A-1002/1A1+1A2	289	292	-0.8	Field corn and grain sorghum
M	A-1002/2	92	99	-7.0	Pasture
N	A-269/7A	332	324	+2.7	Sunflowers
P	A-284/4A	334	321	+3.9	Field corn, tasseling
R	A-1009/13A	332	324	+2.7	Field corn, tasseling
S	A-1028/1	1438	1378	+4.3	Field corn, tasseling
T	O-70/9A	315	324	-1.8	Field corn, tasseling
U	A-102[illegible]/2A	330	326	+1.4	Field corn, tasseling
V	A-1009/1A1+1A2	323	321	+0.6	Popcorn and field corn, tasseling
W	A-1009/2A	312	321	-2.2	Popcorn, tasseling
X	B-1005/1A	324	326	-0.5	Field corn, tasseling
Y	X-104/2 B-1005/2	1159	1198	-3.2	Grass
	Totals	84[illegible]7	8425	-0.1	

[a]Scale calibration field. Scale = 1:130,000.

fields was consistently better than 95 percent with a majority of readings 98 percent or higher. In most cases, the accuracy was undoubtedly influenced by operator familiarity with field shape and training obtained during the area measurements. This introduces a bias which is generally not found when other field shapes are being measured. This was borne out by larger errors found in the noncircular fields. The error in field E was not computed because it was felt that the ground truth was incorrect; all the numerous measurements indicated that this or some other anomaly had occurred.

2. Errors had, on the average, about the same plus or minus values. This is probably indicative of operator as well as instrument error. In this manner, total or combined measurements over large areas were very accurate since errors tended to cancel.

3. Noncircular fields were more difficult to measure and showed a wider range of error (from -6.8 percent to +7.0 percent). Average accuracy was about 96 percent. Border definition was generally poor, especially between circular fields, where there was a spillover of information from the more vigorous circular crops.

4. The results, combined with the experience of the operator, suggest that area measurements should be limited to fields about 12 hectares (30 acres) or larger. Although smaller fields can be measured, the level of confidence would be excessively low and should not be relied upon on a regular basis.

4.1.2.4 Butte County.- The fields selected for area measurement are shown in figure 4-21. Field A was used to

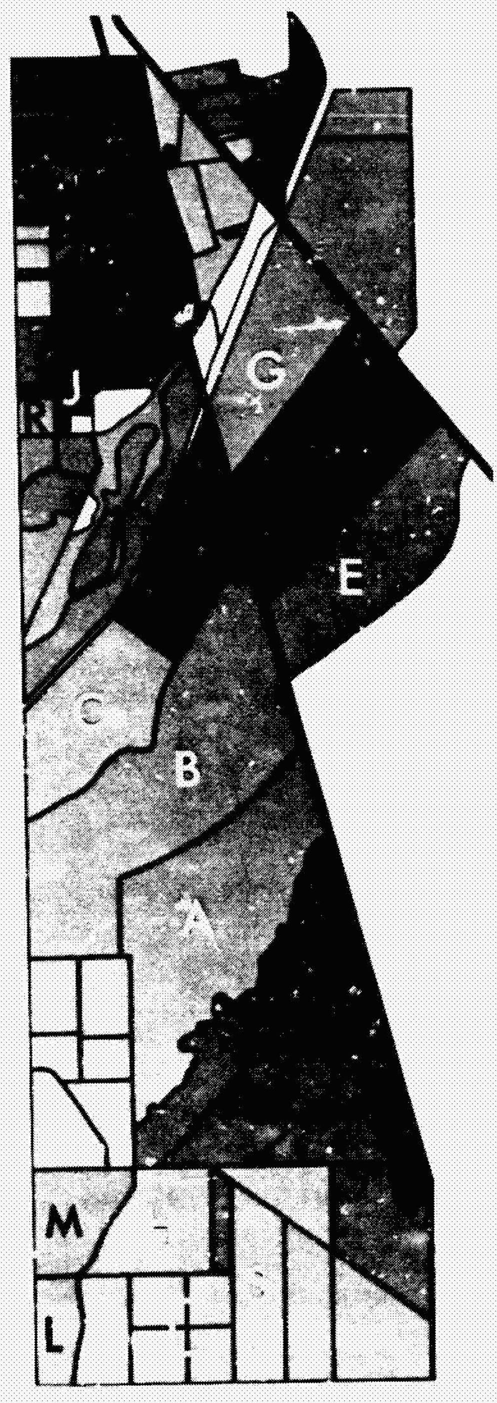

Figure 4-21.- Fields selected for area measurement, Butte County, California.

evaluate and improve instrument calibration because it had relatively well-defined borders. Field selection was based on the detectability of field boundaries and was therefore largely dependent on crop vigor and field size. Much of the test site consisted of harvested crops or dormant vegetation, such as orchard trees. This resulted in the selection of relatively large fields which were predominantly rice or fallow. General comments on the field descriptions follow.

Field	Description
A	Rice nearing maturity; large with well-defined borders.
B	Rice being harvested; large field; light colored with contrasting borders.
C	Corn; large field with good borders or various contrasts.
D,F	Fallow; dark fields with common border.
E,G	Rice; probably with some stubble; light colored.
H	Rice; moderate size; vigorous vegetation; moderate border definition.
I	Rice; probably mature; combination of four fields; moderate size.
J	Alfalfa; small field; strong vegetation response.
K	Fallow; borders of various contrasts.
L,M	Fallow; common border between fields difficult to detect; relatively low-contrast area.
N,P	Fallow; large fields; poor common border; dark fields adjacent on one side.

Field	Description
R	Sugar beets; very small field near limit of measurability; contrasting adjacent fields.
S	Rice; moderate size with generally poor borders especially on the eastern side.

The results of the area measurements are shown in table 4-XXII. Comments on the analysis of the results are as follows.

1. Light areas measured consistently larger than ground-truth figures indicated. The error varied from +0.6 to +2.5 percent and inversely related to field size. Dark fallow fields always resulted in measurements that were low by 1 to 6 percent. (Fields L and M were considered together rather than separately.) Errors for fields R and S were due to poor border definition.

2. Large acreages, at least up to 1619 hectares (4000 acres), can be measured quite accurately from ERTS imagery. On a routine basis, an operator could probably achieve an accuracy of 97 to 98 percent.

3. Field shape appeared to have an insignificant effect on the area measurements. Greatest accuracy is achieved if field borders consist of roads or canals or if adjacent to fields under dissimilar conditions.

4. Although not shown in the data, it took about 45 minutes to measure 18 fields, each about five times. An experienced operator could probably double the number of measurements. Operator fatigue is a serious problem when a data quantizer is used, such as was used here. Fatigue is noticeable after 1 hour and becomes unacceptable after

TABLE 4-XXII.- FIELD AREA MEASUREMENT OF BUTTE COUNTY, CALIFORNIA

[ERTS MSS imagery for September 19, 1972]

Field	Farm/field number	Measured area, hectares	Actual area, hectares	Error, ± %	Remarks
A[a]	1199/1	514.0	516	-0.4	Rice; near maturity
B	1199/6	653.7	650	+0.6	Rice; being harvested
C	1199/7	229.6	231	-0.6	Corn
D	1582/12	128.4	132	-2.7	Fallow
E	1582/30	291.9	287	+1.7	Rice; mature
F	1582/13	226.4	235	-3.7	Fallow
G	1582/11	215.3	210	+2.5	Rice; mature
H	209/2A	151.1	152	-0.6	Rice
I	499/1-4	146.2	150	-2.5	Rice
J	293/11	29.1	31	-6.1	Alfalfa
K	D-1598 1199/2	188.0	190	-1.0	Fallow
L	D-1526 1199/2	56.0	65	-12.3	Fallow
M	209/1	95.1	106	-10.4	Fallow
N	1199/3	236.8	248	-4.5	Fallow
L+M		160.8	171	-6.0	Fallow
N+P	1199/3 1199/4	500.7	527	-5.0	Fallow
R	293/8	20.9	20	+4.5	Sugar beets
S	579/1	150.3	132	+14	Rice
	Totals	3994.3	4053	-1.4 of total	

[a]Used to calibrate image .cale. Scale = 1:130,000.

about 3 hours of effort. Accuracy deteriorates rapidly with operator fatigue.

5. While fields of 8 or 12 hectares (20 or 30 acres) were measured relatively accurately, this should represent a limiting case and not necessarily a working level. Twelve hectares (30 acres) or greater are recommended, depending on field conditions; however, this does not apply to long, narrow fields.

4.1.3 Field Location - UTM Grid

To determine the position of Earth surface features, a UTM grid overlay was prepared for all study areas. These grids are shown in figures 4-22 to 4-27.

Locating a sufficient number of common points on the maps and the enhancements to obtain a best grid fit proved to be difficult in some areas because of the lack of map or image detail. The Hill County grid, for example, was prepared using only four points. Additional reference points would be useful for assessing the presence of distortions in the imagery. However, no significant distortions were present in the imagery of the sites that were checked. The following maps were used to prepare the UTM grids.

1. Hill County - 1:250,000 scale, 1000-meter UTM grid ticks, zone 12. Havre NM 12-12 and Shelby NM 12-11, Montana, USGS.

2. Imperial County - 1:24,000 scale, 1000-meter UTM grid ticks, zone 11. El Centro, Heber, Holtville Est, and Calexico quadrangles, California, USGS.

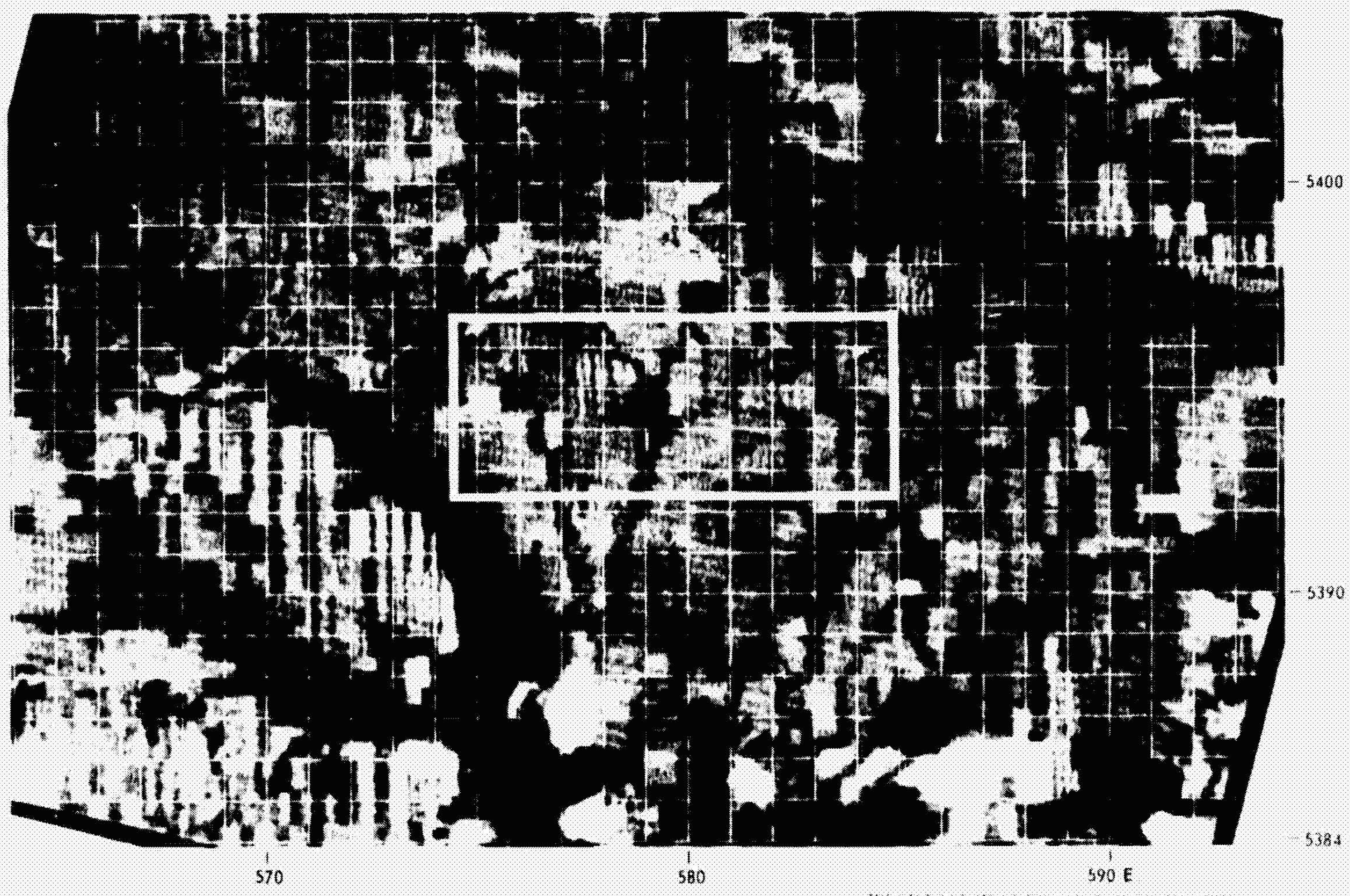

Figure 4-22.- Hill County UTM grid in 1000-meter increments.

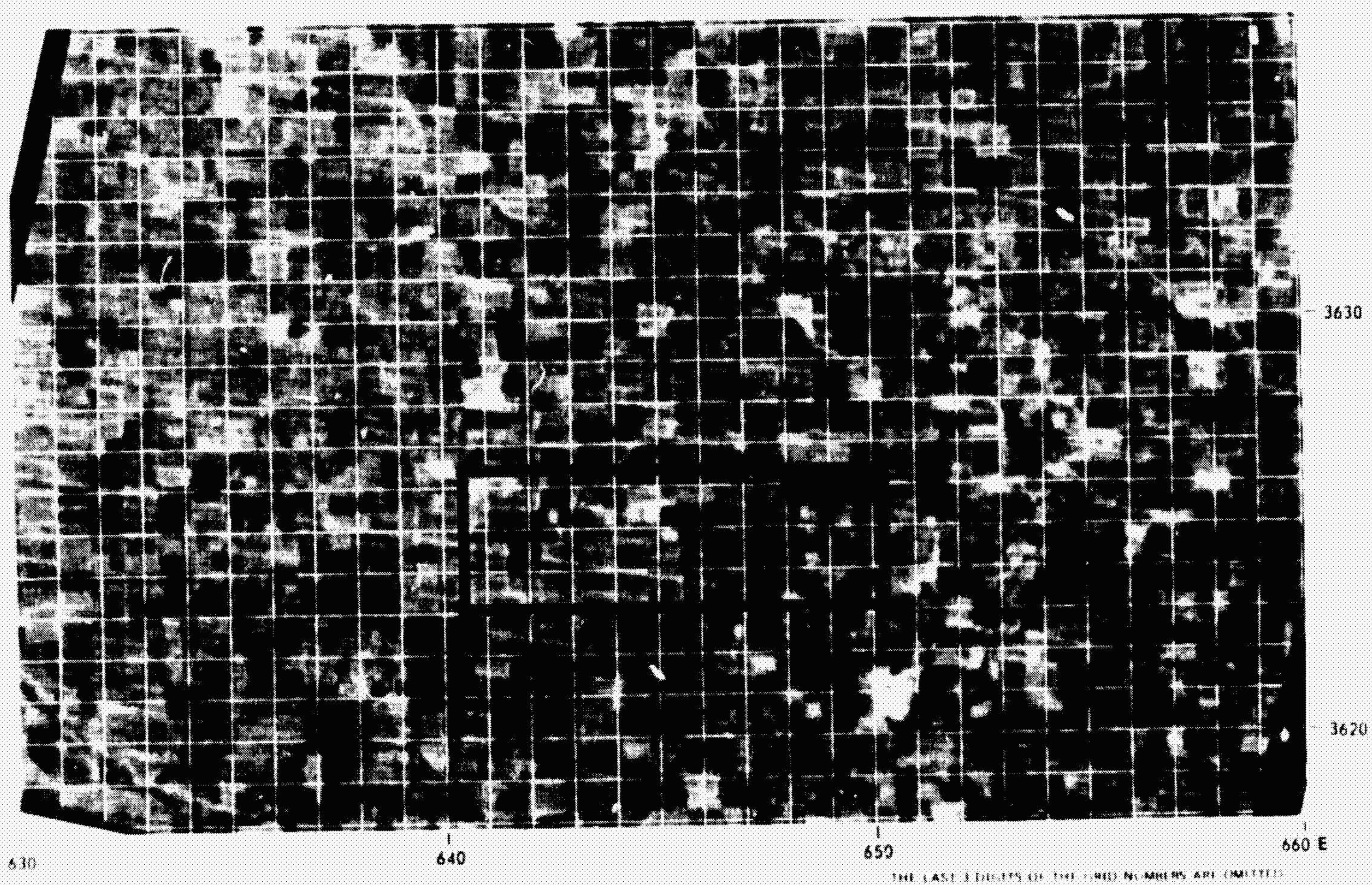

Figure 4-23.- Imperial County UTM grid in 1000-meter increments.

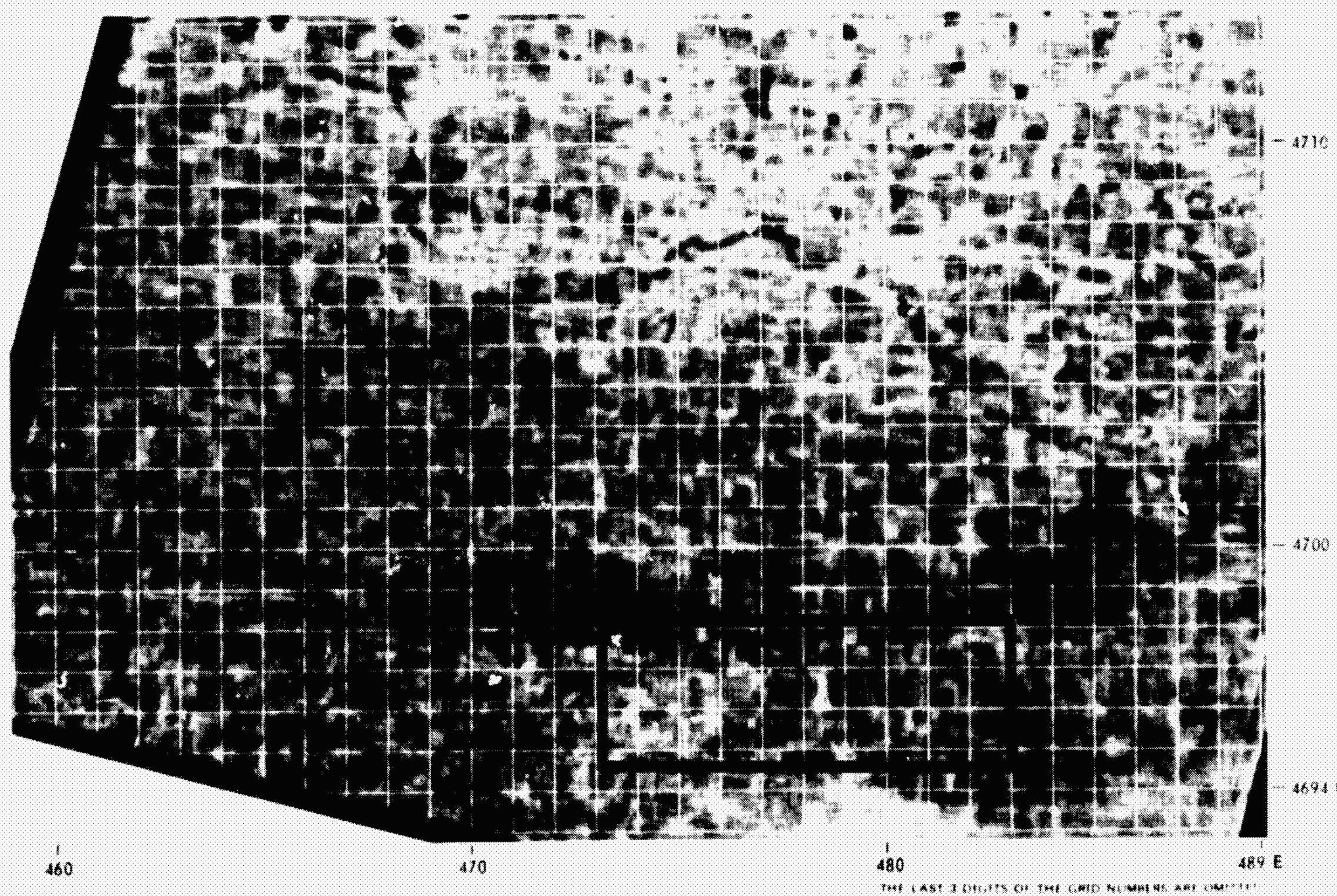

Figure 4-24.- Hardin County UTM grid in 1000-meter increments.

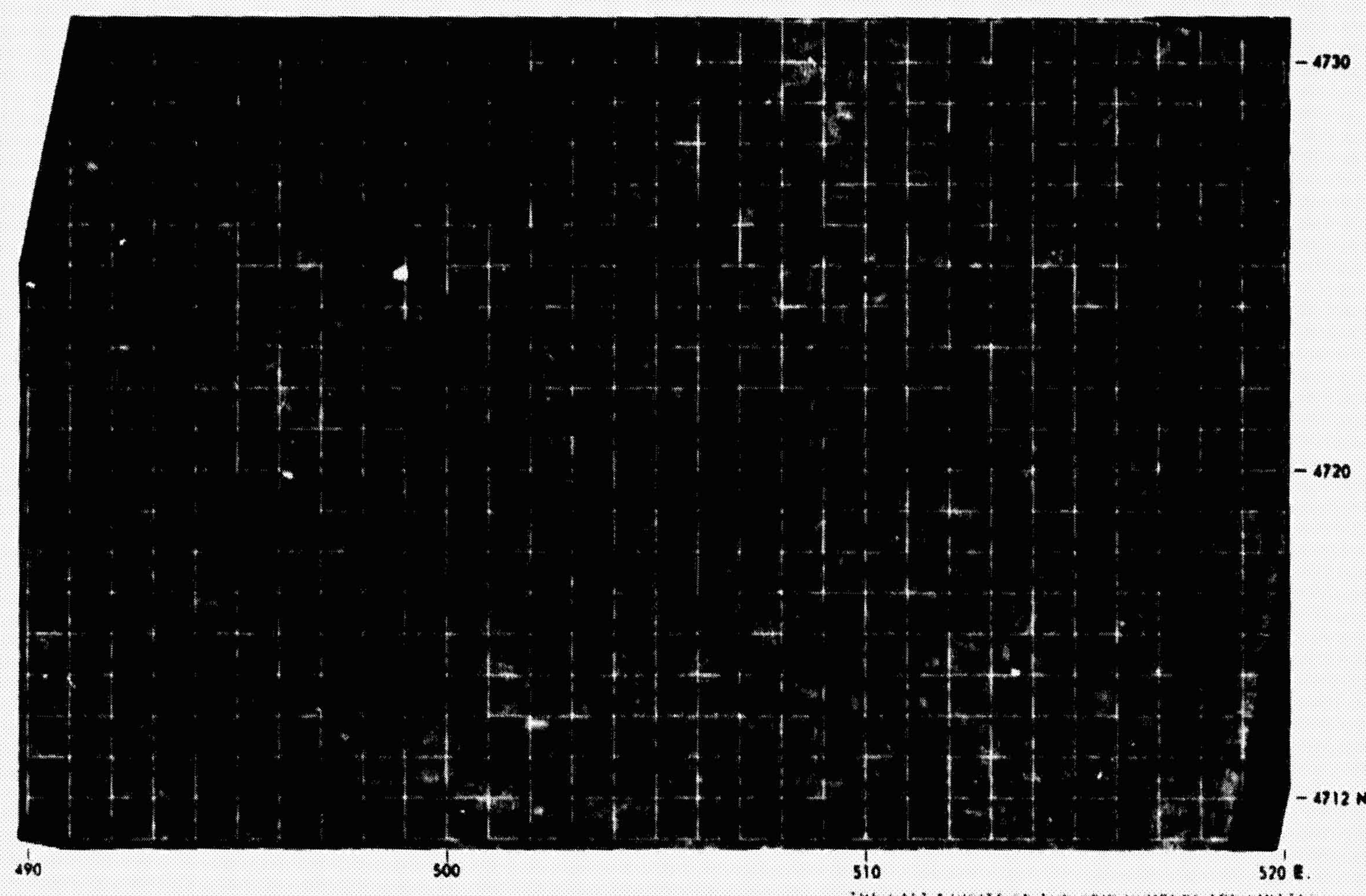

Figure 4-25.- Holt County UTM grid in 1000-meter increments.

Figure 4-26.- Butte County UTM grid in 1000-meter increments.

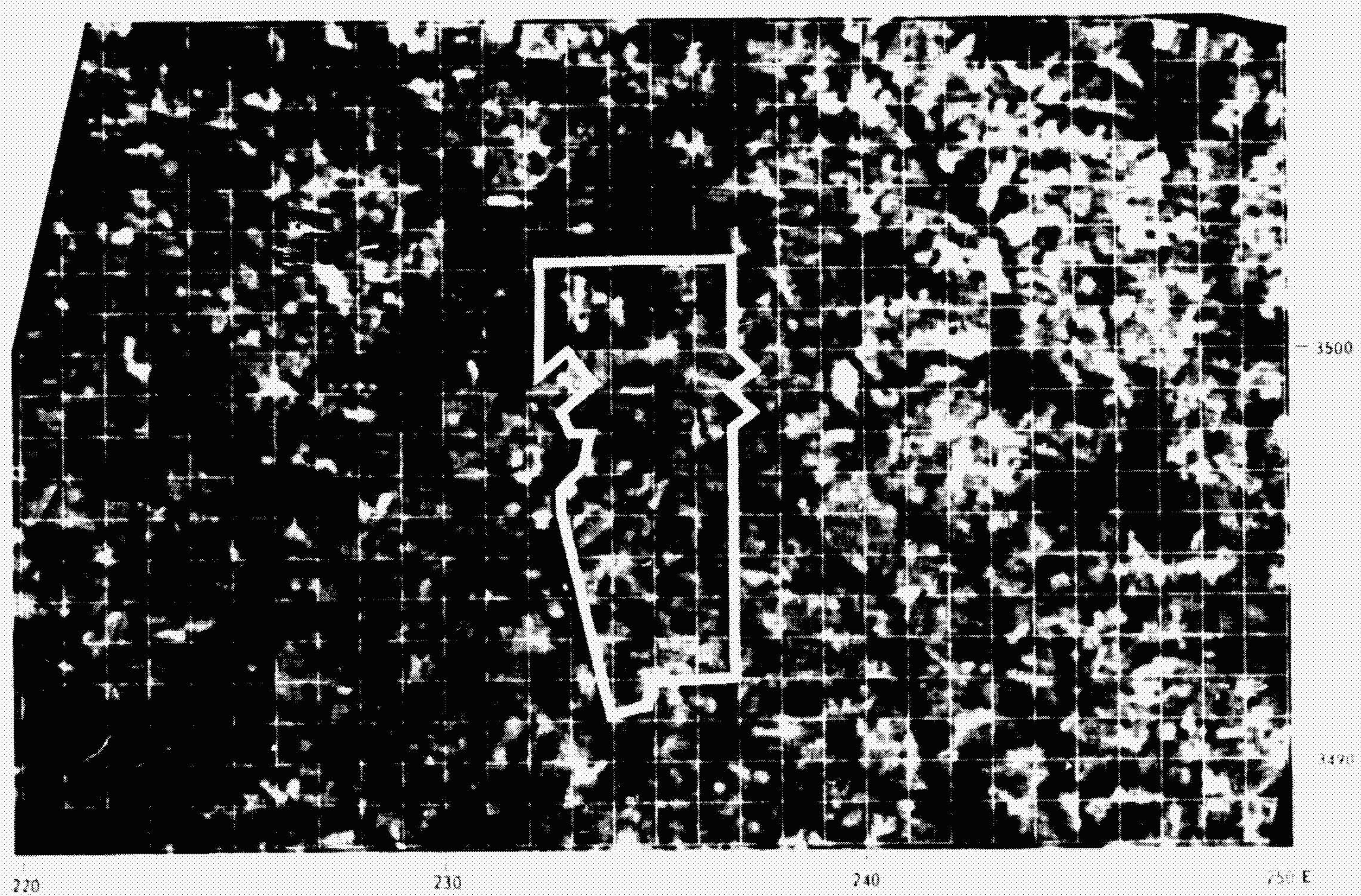

Figure 4-27.- Worth County UTM grid in 1000-meter increments.

3. Hardin County - 1:250,000 scale, 1000-meter UTM grid ticks, zone 15. Waterloo NK 15-5, Iowa, USGS.

4. Holt County - 1:250,000 scale, 1000-meter UTM grid ticks, zone 14. O'Neill, Nebraska - South Dakota, NK 14-5, USGS.

5. Butte County - 1:24,000 scale, 1000-meter UTM grid ticks, zone 10. Shippee and Nelson quadrangles, California, USGS.

6. Worth County - 1:62,500 scale, 1000-meter UTM grid ticks, zone 17. Sylvester quadrangle, Georgia, USGS.

The results of this task are as follows.

1. A UTM grid was prepared that enabled the coordinates of specific features to be readily determined. A comparison of a topographic map and the prepared grid indicates that the grid location accuracies are within 183 meters (600 ft) of the study area. Errors somewhat larger than this may occur elsewhere in the figure.

2. The system-corrected ERTS-1 imagery proved suitable for use as base photographs for a grid overlay to locate fields of a conventional coordinate system. These results are applicable to the image area within the prepared grids only; this area is about 20 by 30 square kilometers (12.5 by 18.7 sq. mi.) or 2.34 percent of a complete ERTS frame.

3. The technique of preparing a family of grid overlays and selecting a grid that provided a best fit was found to be a versatile method for use with standard types of ERTS imagery. The grids can be used with virtually any site photographed by the ERTS where suitable base maps are available.

4.2 COMPUTER-AIDED CROP CLASSIFICATION TECHNIQUE

The results of this investigation have shown that computer-aided techniques can be used to provide good classifications of agricultural features.

The clustering routine ISOCLS was useful for a rough Level I and Level II qualitative classification; that is, the separation of agriculture from nonagriculture and crop-land. However, crop types (Level III) or crop species (Level IV) were not satisfactorily separated in all the study areas using this technique. Smaller fields blurred into an unidentifiable hodgepodge. Field sizes of 10 to 12 hectares (25 to 30 acres) were the minimum for computer crop identification.

Atmospheric correction techniques were not used in the computer-aided analysis because of the lack of ground data. Photometers which would have measured the effect of the atmosphere on the total solar energy reaching the Earth were not available for the test sites during the ERTS-1 overpasses.

4.2.1 Hill County

The major crops grown on the Hill County site had either been harvested or were ready for harvest. In addition to the advanced stage of maturity, the narrow width of a majority of the alternating strips made it very difficult, if not impossible, to select training and test fields of sufficient size to achieve other than a limited classification.

An analysis of the results from the Hill County site in August indicated that fields of less than 24 hectares (60 acres) which were over 800 meters (0.5 mi.) long could not be properly defined for use as training or test fields on the interactive classification system. These narrow fields had a higher percentage of pixels comprising mixtures at the boundary and therefore might not represent the data from that field. Many fields in the area were 1609 meters (1 mi.) long, which meant they must be greater than 40 hectares (100 acres) to be wide enough for use as a dependable training and/or test field. Very few fields could meet these criteria. In contrast, fields as small as 8 hectares (20 acres) made dependable training and/or test fields provided that the strips were less than 400 meters (0.25 mi.) long and adjacent to summer fallow strips. The high relative contrast between the small grain crops and summer fallow strips provided an excellent boundary discrimination until the crop was harvested; then the contrast was greatly reduced. Table 4-XXIII shows the accuracy percentages for the training and test fields.

The classification results are best shown by the comparison of the ground-truth map for the 19-square-kilometer (12-sq.-mi.) test site (fig. 3-10) with the recognition maps developed (figs. 4-28 to 4-30). Crop identification accuracy was computed with the following formula.

Percent accuracy of field identification =

$$\frac{\text{Number of pixels per feature (test or training field) identified (100)}}{\text{Total pixels per test or training field}}$$

TABLE 4-XXIII.- HILL COUNTY, MONTANA, CLASSIFICATION PERFORMANCE SUMMARY TRAINING AND TEST FIELDS

Crop	No. samples	Barley	Spring wheat	Winter wheat	Fallow	Sod	Correct classification, %
Training field class							
Spring wheat	143	33	93	9	7	1	65.0
Winter wheat	184	34	8	135	4	3	73.4
Barley	147	129	9	4	4	1	87.8
Fallow	188	7	3	3	164	11	87.2
Sod	173	2	3	3	13	155	89.6
Test field class							
Spring wheat	52	11	35	6	0	0	67.3
Winter wheat	99	18	49	27	5	0	27.3

Crop	No. samples	Barley	Wheat	Fallow	Sod	Correct classification, %
Training field class						
Wheat	327	67	245	11	4	74.9
Barley	147	129	13	4	1	87.8
Fallow	188	7	6	164	11	87.2
Sod	173	2	6	13	155	89.6
Test field class						
Wheat	151	[illegible]	117	5	0	77.5

Crop	No. samples	Small grains	Fallow	Sod	Correct classification, %
Training field class					
Small grains	474	454	15	5	95.7
Fallow	188	13	164	11	87.2
Sod	173	8	13	155	89.6
Test field class					
Small grains	151	146	[illegible]	0	96.7

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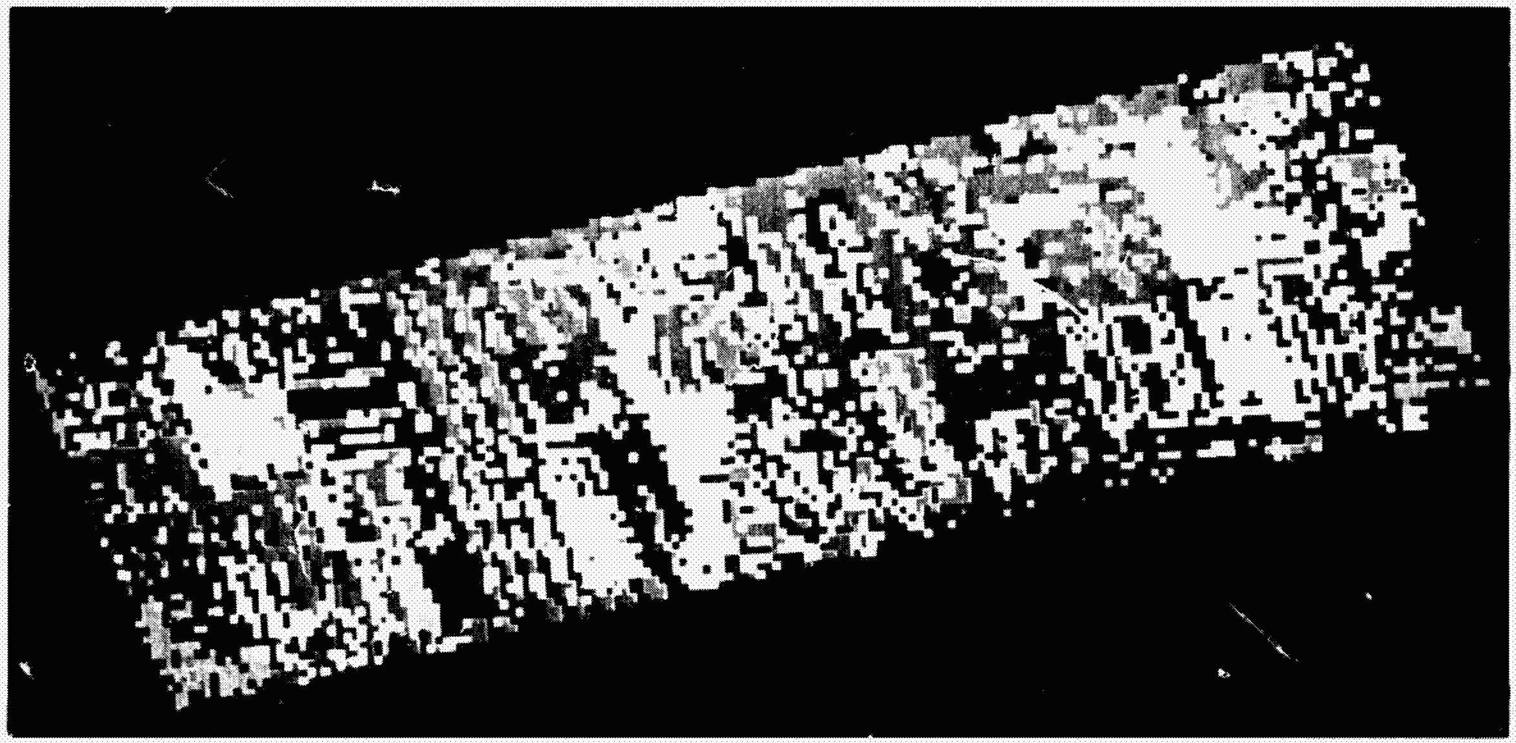

CROP	COLOR
Spring Wheat	Red
Winter Wheat	Green
Barley	Yellow
Fallow	Brown
Sod	Tan

Figure 4-28.- Hill County computer analysis with three grain classes.

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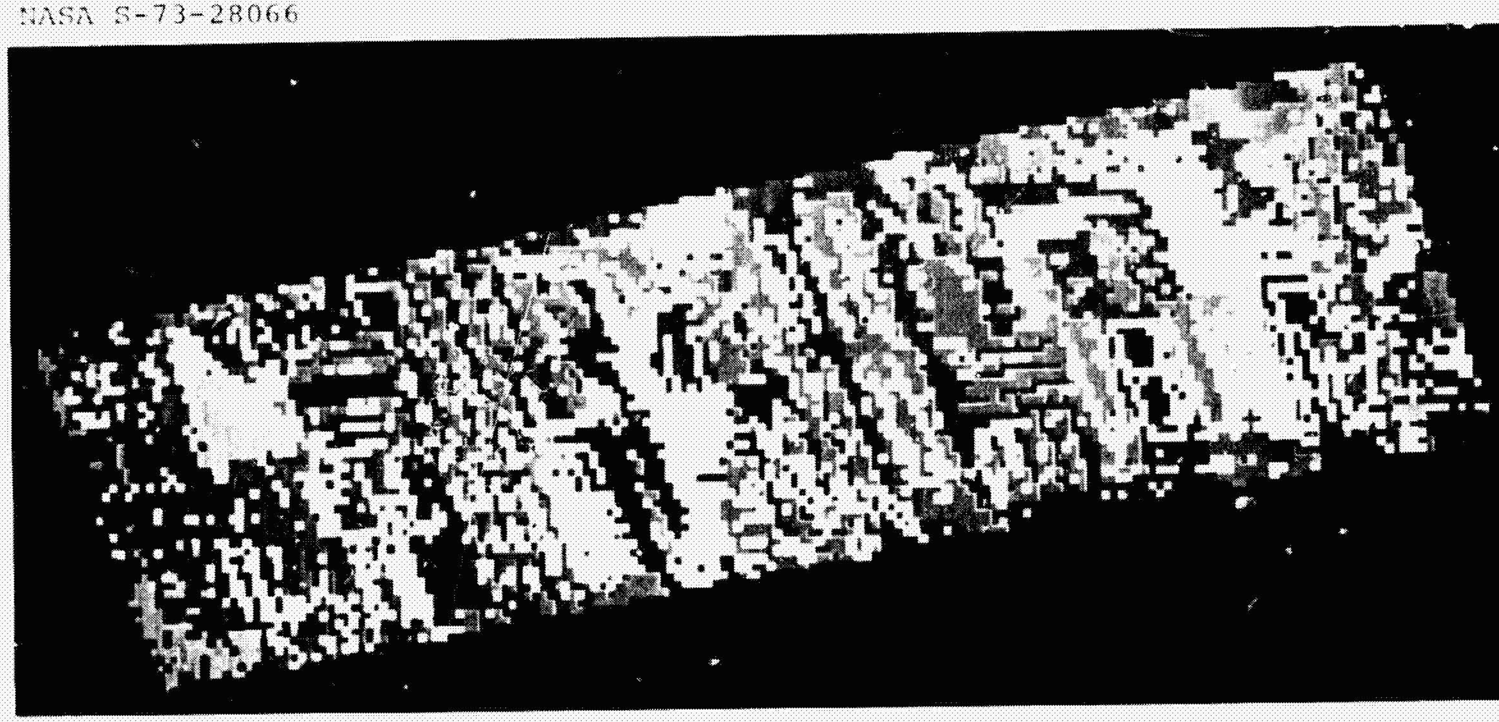

CROP	COLOR
Wheat	Green
Barley	Yellow
Fallow	Brown
Sod	Tan
Training, Test	Pink

Figure 4-29.- Hill County computer analysis with two wheat classes combined.

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CROP	COLOR
Small Grains	Blue, Dark Brown
Fallow	Brown
Sod	Tan
Training, Test	Pink

Figure 4-30.- Hill County computer analysis with all small grain classes combined.

Oats were grown in the Hill County sites; however, no classification attempt was made because the oats had been harvested at the time of the overpass and no field was large enough for use as a training field.

Figure 4-28 represents the classification results of all five classes: barley (yellow), fallow (brown), sod (tan), spring wheat (red), and winter wheat (green). Figure 4-29 represents the classification results when the two wheat classes were combined and are shown as a single class: barley (yellow), fallow (brown), sod (tan), and wheat (green). Figure 4-30 shows the results obtained when all small grains were combined and are shown as a crop type: fallow (brown), sod (tan), and small grains (blue and dark green).

The sod and fallow classes could be discerned individually and from the other classes. The small grains (barley, spring wheat, and winter wheat) could be separated from sod and fallow, but could not be separated from each other with any degree of confidence with this single data set. The difficulty in separating the individual small grains was due to close overlapping spectral response. Each small grain crop was at or near the maturity growth stage.

The classification accuracies (table 4-XXIII) of the small grain crop types increased significantly when the various groupings were combined. The wheat class increased from 65 percent for spring wheat and 73 percent for winter wheat to 75 percent for the combined class. When barley was added to the grouping, the accuracy increased from 75 percent for wheat and 88 percent for barley to 96 percent for small grain crop types. The results for the test fields showed similar results.

The results of the investigation depended heavily on the selection and location of the training and test areas. The long, narrow fields did not provide the best conditions for the selection and location of training and test fields to provide a high degree of confidence. Notwithstanding, it is felt that the three classes of fallow, sod, and small grains can be discriminated with better than 90 percent accuracy during this phase of the growing season.

4.2.2 Imperial County

The Purdue clustering routine and ground-truth information were used to select eight different crop types and species for classification training and testing. Although corresponding test fields were not available, additional training fields were selected so that the classification would be a fairly accurate representation of the actual ground scene. The classification results are presented in table 4-XXIV, a computer printout classification map (fig. 4-31), and a color-coded classification map (fig. 4-32).

Bare soil was the most easily discriminated group. The classification test results for each of the bare soil classes were 90 percent and 65.6 percent, a composite accuracy of 83 percent. The composite accuracy of bare soils increased to 93 percent when the ground-truth reports (fig. 3-11) were considered because sorghum was classified as essentially bare soil. This accuracy was slightly less than the 95 percent accuracy for alfalfa. The alfalfa accuracy figure was based on a training data accuracy of only 75 percent, which indicates that bare soil classification results are more valid than for alfalfa.

TABLE 4-XXIV.- COMPUTER CLASSIFICATION OF IMPERIAL COUNTY, CALIFORNIA, NOVEMBER 6, 1972

Field designated group	No. of samples	Percent correct	Number of samples classified into -									
			Carrots	Bare soil 1	Bare soil 2	Beets	Alfalfa	Asparagus	Cotton	Sudan-grass	Sorghum	Melons
Training field performance												
Carrots	24	100	24	0	0	0	0	0	0	0	0	0
Bare soil 1	24	100	0	24	0	0	0	0	0	0	0	0
Bare soil 2	48	100	0	0	48	0	0	0	0	0	0	0
Beets	0	100	0	0		9	0	0	0	0	0	0
Alfalfa 1	12	25.0	1	0	0	0	3	6	0	2	0	0
Alfalfa 2	24	100	0	0	0	0	24	0	0	0	0	0
Alfalfa 1 and 2[a]	36	75.0	1	0	0	0	27	6	0	2	0	0
Asparagus 1	42	97.6	0	0	0	0	0	41	1	0	0	0
Asparagus 2	32	62.5	1	0	0	0	9	20	1	1	0	0
Asparagus 1 and 2[a]	74	82.4	1	0	0	0	9	61	2	1	0	0
Cotton	28	100	0	0	0	0	0	0	28	0	0	0
Sudangrass	16	100	0	0	0	0	0	0	0	16	0	0
Sorghum	15	100	0	0	0	0	0	0	0	0	15	0
Melons	12	100	0	0	0	0	0	0	0	0	0	12
Total	286		26	24	48	9	36	67	30	19	15	12
Overall performance (264/286) = 92.3												
Test field performance												
Carrots	32	71.9	23	0	0	0	3	3	0	3	0	0
Bare soil 1	32	65.6	0	21	0	0	0	0	0	0	11	0
Bare soil 2	70	90.0	0	0	63	0	0	0	7	0	0	0
Beets 1	20	95.0	0	0	0	19	0	0	0	1	0	0
Beets 2	25	0.0	0	9	0	0	1	0	0	0	14	1
Beets 1 and 2[a]	45	42.2	0	9	0	19	1	0	0	1	14	0
Alfalfa	24	95.8	0	0	0	0	23	0	1	0	0	0
Asparagus 1	80	95.0	0	0	0	0	1	76	2	1	0	0
Asparagus 2	56	55.4	2	0	0	0	12	31	10	1	0	0
Asparagus 1 and 2[a]	136	78.7	2	0	0	0	13	107	12	2	0	0
Cotton 1	27	63.0	0	0	0	10	0	0	17	0	0	0
Cotton 2	48	100	0	0	0	0	0	0	48	0	0	0
Cotton 1 and 2[a]	75	86.7	0	0	0	10	0	0	65	0	0	0
Sudangrass	24	91.7	0	0	0	0	2	0	0	22	0	0
Total	438		25	30	63	29	42	110	85	28	25	1
Overall performance (343/438) = 78.3												

[a]Average of fields 1 and 2.

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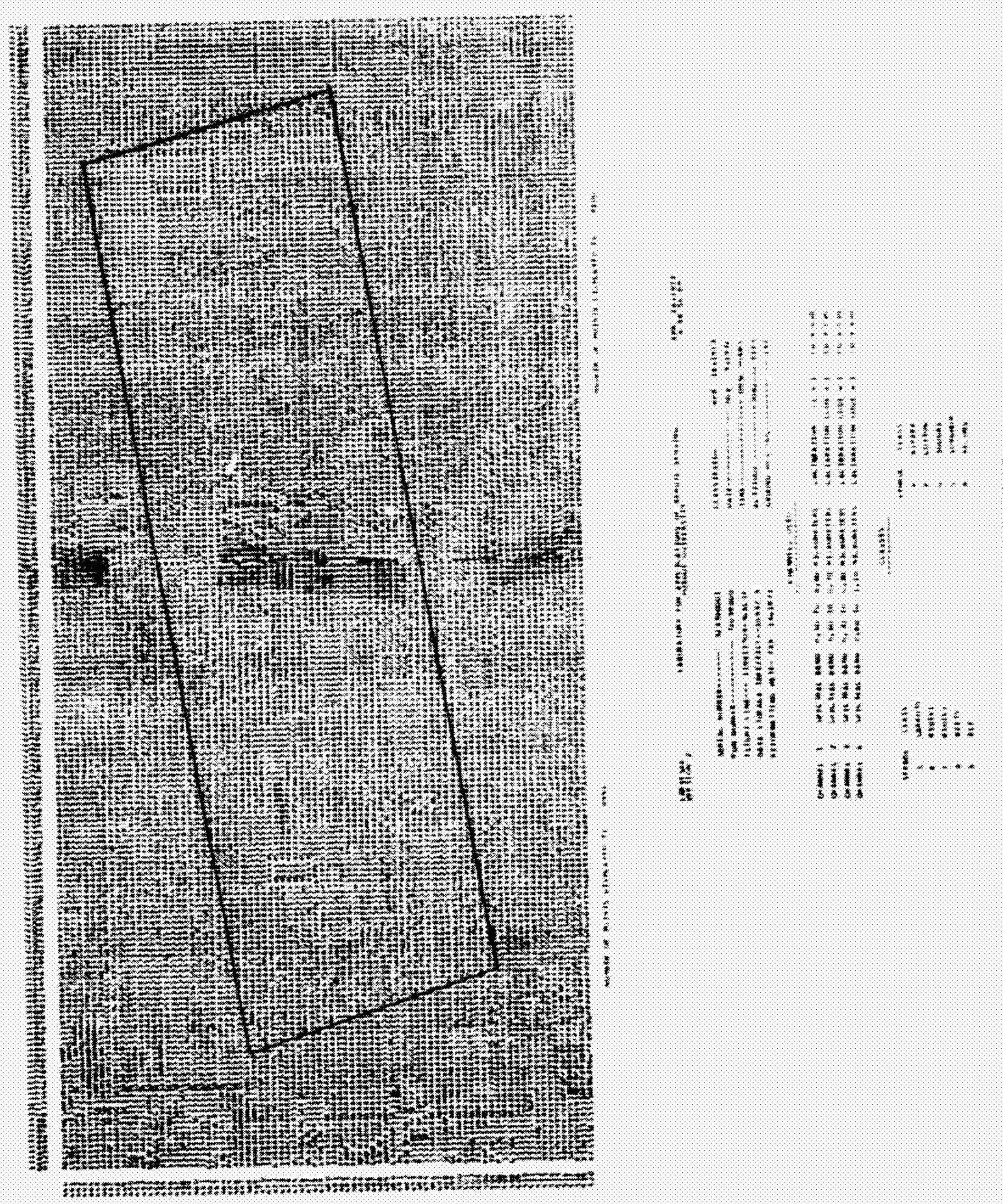


Figure 4-31.- Imperial County computer printout classification map.

CROP	COLOR
Carrots	Light Brown
Bare Soil 1	Light Green
Bare Soil 2	Light Blue
Beets	Dark Blue
Alfalfa	Pink
Asparagus	Dark Brown
Cotton	Light Brown
Sudangrass	White

Figure 4-32.- Imperial County computer-aided classification of November 6, 1972, imagery.

Cotton, asparagus, and carrots had classification results of 71 to 86 percent. One of the two asparagus test fields was classified with a 95-percent accuracy. The other asparagus field had a classification accuracy of 55 percent. The only difference in the two fields (described in the ground-truth report) was the row direction. This minor difference should not have created a 40-percent classification result difference; rather, it might have been expected that the effects of the row direction would be negligible.

Beets presented the worst test classification accuracy, with 42 percent of the two fields correctly classified. The one test field of beets was a very young stand with a high percentage of soil showing. It is understandable, then, that 32 percent of the beetfield would be classified as bare soil and 56 percent as sorghum.

The accuracy on the test fields ranged from 42 percent for beets to 95 percent for alfalfa, with an overall performance of 78 percent. Table 4-XXIV shows the performance figures for the training and test fields outlined in yellow in figure 4-32.

4.2.3 Hardin County

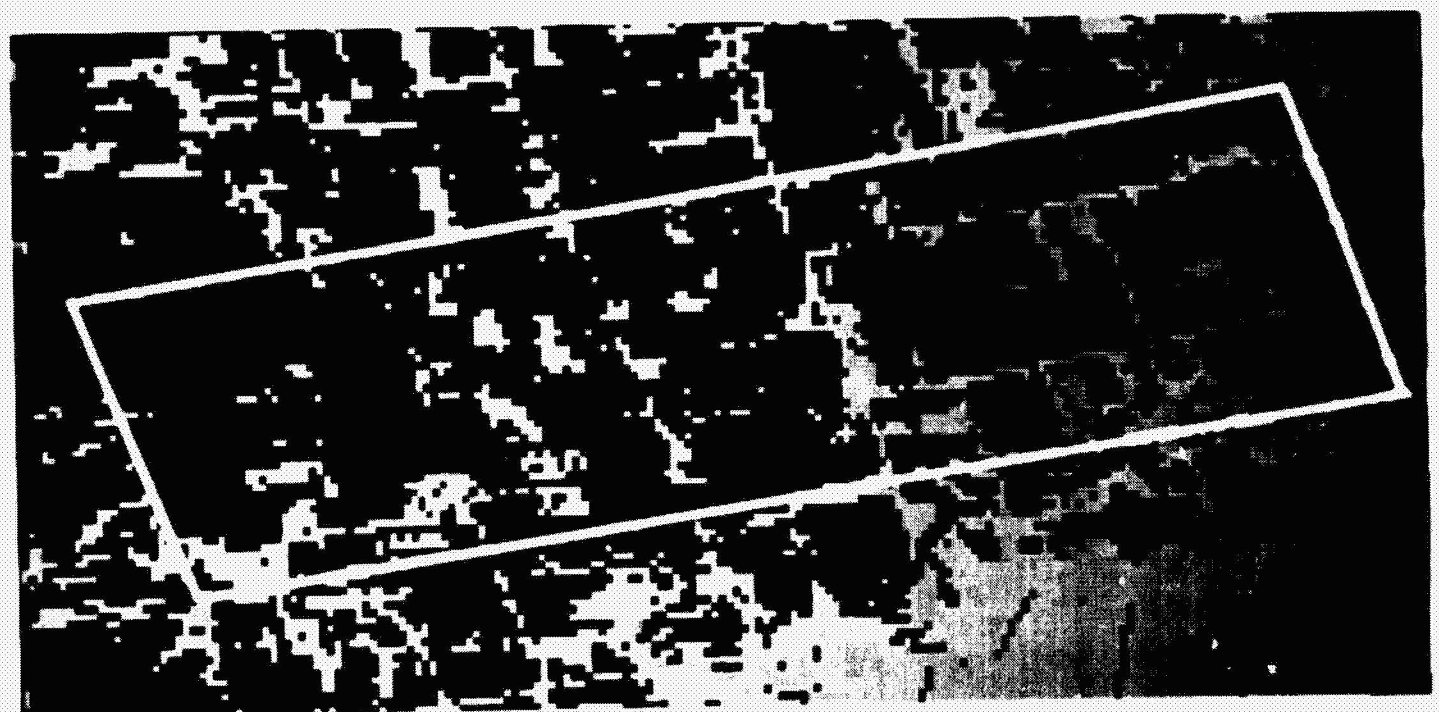
Corn was represented by a number of large areas on the ERIPS classification and was fairly well defined. A total of 76 cornfields was represented on the ground-truth tabulation, and of these 73 were classified by the ERIPS classifier. The three fields unaccounted for were small individual fields beyond the expected resolution limit. The larger fields were fairly well defined with little extraneous data. The thin cloud to the south of the study area cast a weak shadow along the northern edge of the area, which caused other crop types in this area to be grouped with the corn. One test cornfield was partially shadowed, and when this field was removed the test results increased to above 80 percent. A breakdown of eight classes is provided in table 4-XXV.

Statistically, the classification results were reasonably good and indicated that corn, soybeans, and oats could be separated at this maturity stage (test results from table 4-XXV). A review of the input showed that one of several things happened in almost all cases of low classification accuracy. The most frequent occurrence was improperly defined boundaries overlapping another crop type; this problem was expected since this was an area with many small fields (fig. 3-12). Judicious screening of the training and test fields (shown in pink on fig. 4-33) overcame this problem. A second problem area was that all oats had been harvested nearly a month before the overpass and were in various stages of regrowth or bare soil. Despite this, the classification was fairly successful, except for an inability to distinguish some oats from county and state roads. Farm roads in Iowa are normally bordered by wide, shallow ditches of mowed bluegrass, which appeared spectrally similar to harvested oats. A third problem was presented by the cloud shadow which was cast over the northwest corner of the study area. Unique signatures for this cloud shadow area were not developed.

TABLE 4-XXV.- CLASSIFICATION PERFORMANCE SUMMARY FOR HARDIN COUNTY, IOWA

Crop	No. of samples	Corn	Soybeans	Oats	Sorghum	Sudan	Bare soil	Cloud	Shadow	Accuracy, %
Training field										
Corn	419	380	1	8	21	0	2	0	7	90.7
Soybeans	267	0	220	11	17	15	0	0	4	82.4
Oats	106	2	2	86	4	1	10	0	1	81.1
Sorghum	56	0	3	1	52	0	0	0	0	92.9
Sudangrass	47	0	4	0	2	41	0	0	0	87.2
Bare soil	58	3	0	6	0	0	49	0	0	84.5
Cloud	491	0	0	2	0	0	0	489	0	99.6
Shadow	131	1	3	0	1	0	0	0	126	96.2
Test fields										
Corn	309	223	6	14	14	0	9	0	[a]43	72.2
Soybeans	141	1	128	0	5	5	0	0	2	90.8
Oats	85	1	5	64	4	2	8	1	0	75.3
Cloud	365	0	0	1	0	0	0	364	0	99.7
Shadow	98	5	0	0	3	0	5	0	85	86.7

[a]Test cornfield partially shadowed; removal of this data increased corn test results to above 80 percent.

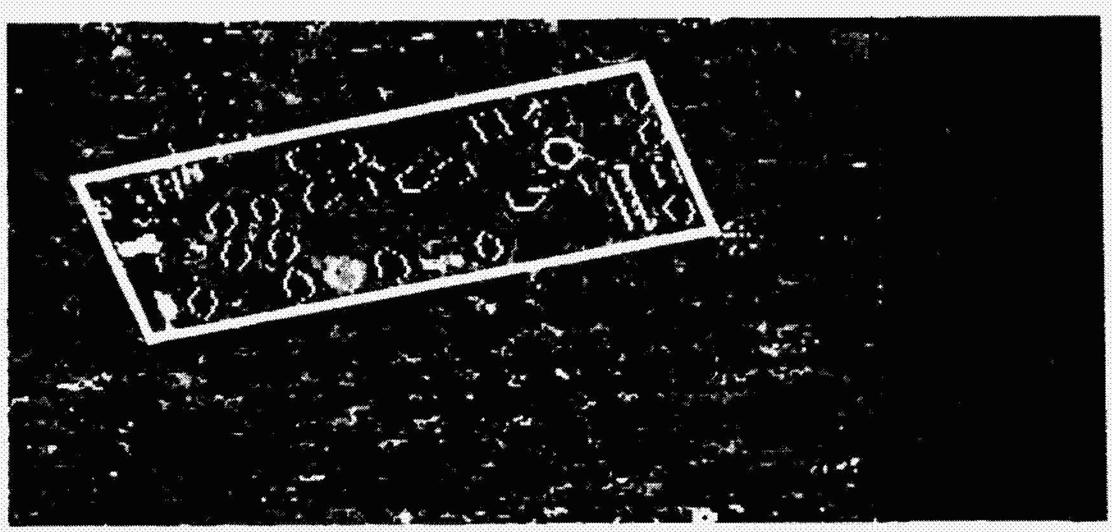


CROP	COLOR
Corn	Red
Soybeans	Blue
Oats	Yellow
Sorghum	Green
Sudangrass	Light Blue
Bare Soil	Brown
Cloud	White
Shadow,	Brown, Black

Figure 4-33.- Hardin County supervised computer classification (August 13, 1972).

4.2.4 Holt County

These fields were analyzed in two phases. First, four channels of ERTS-1 MSS data were analyzed for a single pass on July 30, 1972 (fig. 4-34). In the second phase, the August 16, 1972, pass was correlated and registered to the first to form a single data set. These were analyzed temporally using a 0.5 and 0.2 threshold (figs. 4-35 and 4-36). The 0.2 threshold appears to be better (shown in table 4-XXVI). The results indicate that the data contain the information necessary to separate the following crop species: corn (field corn or popcorn) sunflowers, alfalfa at a certain stage of growth, grass, pasture, and fallow land (bare soil). An upper limit of the classification accuracy may be extracted from table 4-XXVI. The ground-truth information (fig. 3-13) was insufficient to obtain a good statistical estimate of the lower limit classification accuracy. To achieve this would require highly accurate ground truth over a much larger area in order to obtain a good statistical sample of every variation of every crop. The only possible exception was the species corn (field corn or popcorn) in which it was possible for the most part to accept the accuracy figures shown in table 4-XXVI. It should be pointed out, however, that these figures represent averages of overall training or test fields used in the analysis. Some specific cornfields have spectral characteristics very close to those of one of the other species, such as alfalfa and pasture on one side of corn and sunflowers on the other side. All available fields in this category were used as training fields. Therefore, there may be single fields with classification accuracy considerably worse than 95 percent, which was the lowest figure obtained for a test cornfield.



CROP	COLOR
Field Corn and Popcorn	Red
Sunflowers	Orange
Alfalfa and Grass	Light Violet
Alfalfa	Dark Violet
Grass	Light Green
Pasture	Dark Green
Bare Soil	Gray-Brown

Figure 4-34.- Holt County four-channel MSS data from July 30, 1972, pass.

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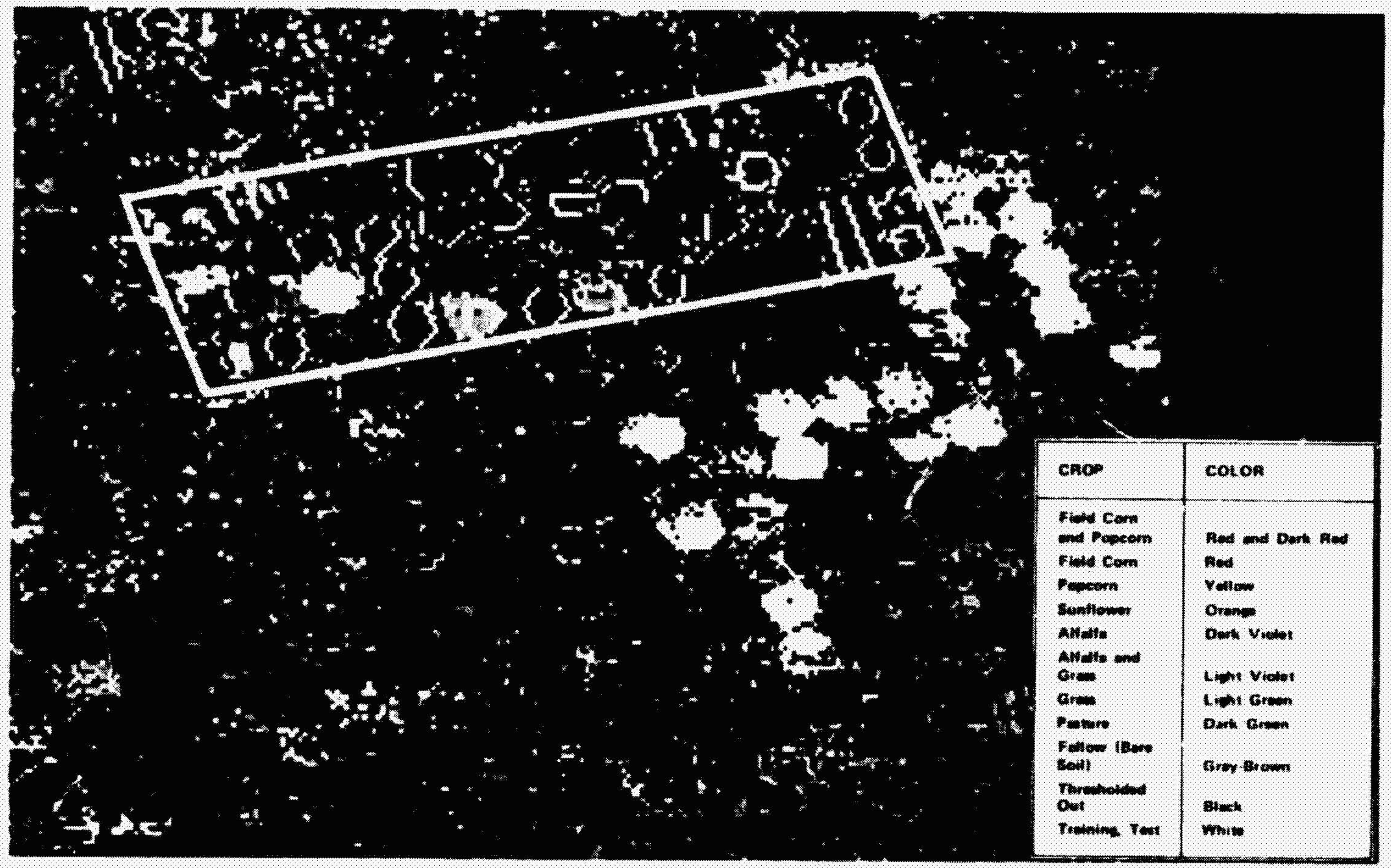

Figure 4-35.- Holt County temporal analysis (threshold 0.5).

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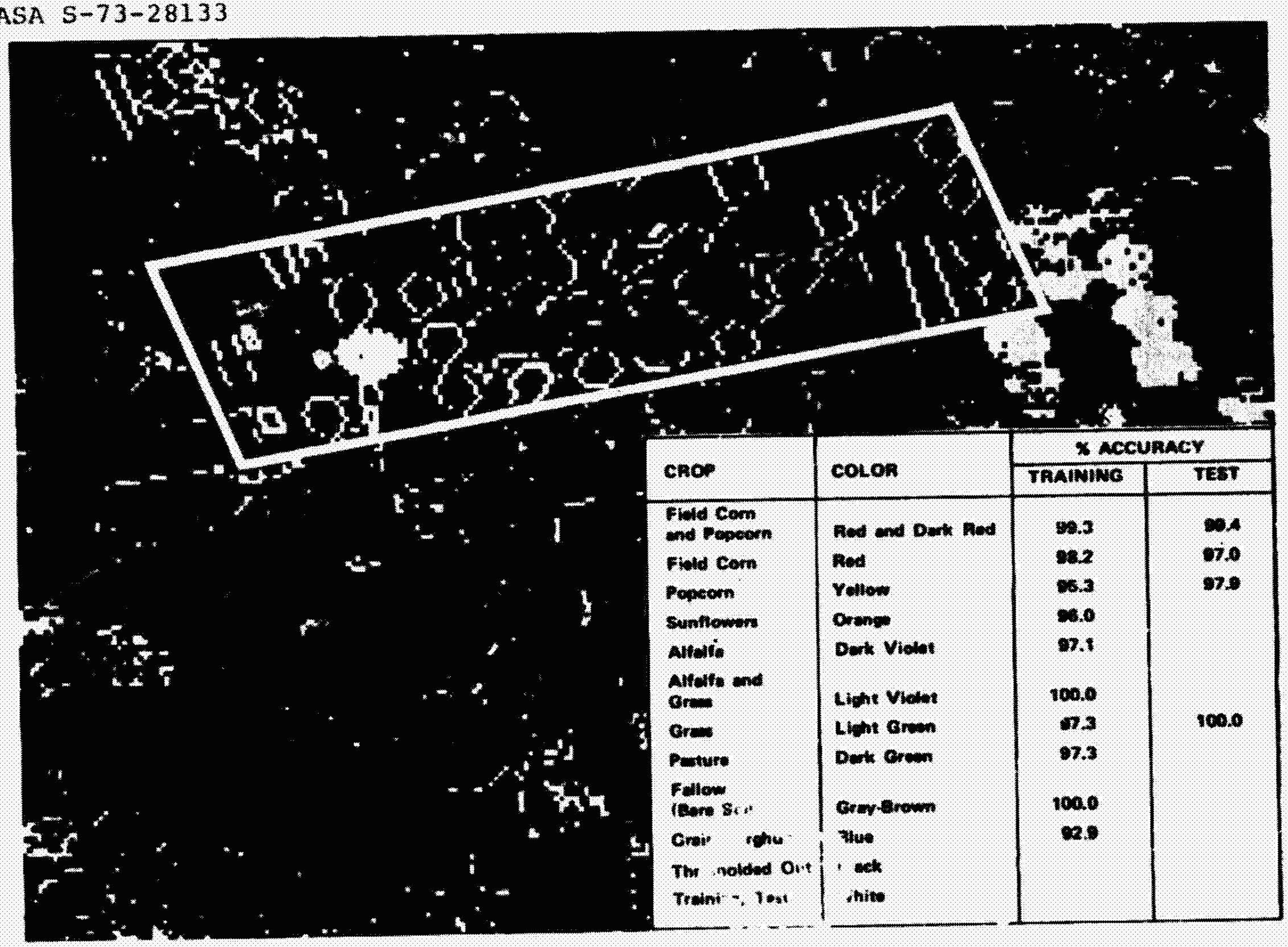

CROP	COLOR	% ACCURACY TRAINING	% ACCURACY TEST
Field Corn and Popcorn	Red and Dark Red	99.3	98.4
Field Corn	Red	98.2	97.0
Popcorn	Yellow	95.3	97.9
Sunflowers	Orange	96.0	
Alfalfa	Dark Violet	97.1	
Alfalfa and Grass	Light Violet	100.0	
Grass	Light Green	97.3	100.0
Pasture	Dark Green	97.3	
Fallow (Bare Soil)	Gray-Brown	100.0	
Grain Sorghum	Blue	92.9	
Thresholded Out	Black		
Training, Test	White		

Figure 4-36.- Holt County temporal analysis (threshold 0.2).

TABLE 4-XXVI.- HOLT COUNTY CLASSIFICATION PERFORMANCE SUMMARY

Crop	Data set 1 (single pass) 4-channel classification threshold = 0.5 July 30, 1972				Data set 2 (two-pass) 7-channel classification threshold = 0.5 August 16 and July 30, 1972				Data set 2 (two-pass) 7-channel classification threshold = 0.2 August 16 and July 30, 1972			
	Total points	Mis-class.	Threshold out	Correct, %	Total points	Mis-class.	Threshold out	Correct, %	Total points	Mis-class.	Threshold out	Correct, %
Training fields												
Field corn or popcorn	789	4	4	99.0	1038	7	14	98.8	979	4	1	99.3
Field corn	--	--	--	--	768	31	10	94.7	745	13	1	98.2
Popcorn	--	--	--	--	270	13	4	[a]95.1	234	9	2	[a]95.3
Sunflowers	51	1	0	98.0	49	1	0	98.0	50	2	0	96.0
Alfalfa	34	5	0	85.3	29	0	2	91.2	34	1	0	97.1
Alfalfa and grass	25	7	0	68.0	29	1	0	96.6	18	0	0	100.0
Grass	96	3	1	95.8	97	4	1	94.8	109	3	0	97.3
Pasture	232	18	1	91.8	211	3	1	98.2	219	4	2	97.3
Fallow (bare soil)	34	0	0	100.0	44	0	0	100.0	50	0	0	100.0
Grain sorghum	--	--	--	--	--	--	--	--	14	1	0	92.9
Test fields												
Field corn or popcorn	686	17	0	97.5	478	3	0	98.1	504	3	0	99.4
Field corn	--	--	--	--	428	20	9	93.2	456	13	0	97.0
Popcorn	-	--	--	--	50	0	0	[a]100.0	48	1	0	[a]97.9
Grass	39	0	0	100.0	50	0	0	100.0	54	0	0	100.0

[a]This number does not reflect that one out of the seven known popcorn fields was misclassified as field corn.

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The results of the first and second phases of analyses are summarized by crop species.

Field Corn and Popcorn - The classification accuracy for the identification of known test cornfields was about 97 to 98 percent for both data sets. The single-pass data set did not contain the necessary information to separate popcorn from field corn. Distinguishing field corn from popcorn was attempted using a two-pass data set and was successful for one particular field. This was possible because the reflectance of popcorn fields in channels 3 and 4 of the ERTS-1 MSS in the August 16, 1972, pass was higher than that of field corn. Such a spectral response may well be due to some peculiarity in the development of popcorn that is different from that of field corn. For example, popcorn matures faster than field corn.

Sunflowers - This class was separable from corn because of its higher reflectance in the third channel of the single-pass data sets of July 30, 1972. At this stage the sunflowers were blooming. Sunflowers were not separable from corn, particularly popcorn, using the August 16th data only.

Alfalfa - The study site contained only a few small fields of alfalfa, some of which had recently been harvested at the time of both ERTS-1 passes. Alfalfa fields were classified as either pasture or grass in the second pass. Specifically, for the data of the first ERTS-1 pass only two fields of usable size were identified at or near the blooming stage during the second pass. These two fields were used as training fields for both data sets. Together they comprised a total of about 30 data points. The accuracy of classification for these fields was 85 percent for the single-pass data set and 90 percent for the two-pass data set.

Pasture and Grass - These two classes were well separable from the other classes of the study site, as well as between themselves. The pasture was divided into three subclasses, one of which was bromegrass. The distribution of bromegrass data overlapped the other types of grasses in the study site, in some cases by as much as 50 percent. Bromegrass was therefore not separable from other grasses in the area.

Fallow Land (Bare Soil) - Bare soil has unique spectral response and was well separable from all types of vegetation. The two fallow fields in the study site were assigned to the same class, although the combined distribution of the data was definitely bimodal. No difference was discernible in the classification maps, which were generated by assigning the two fallow fields to either the same or to different subclasses. This was true for the two-pass data set, even though some of the fallow fields seemed to be overgrown with vegetation at the second pass. Positive recognition of fallow fields may require that one of the two passes be made when the field is primarily bare soil.

4.2.5 Butte County

Preliminary screening on the DAS allowed more accurate location of the test site. The segment of the tape which represented the test site was reformatted to the LARSYS II format for input to the clustering and classification programs. The results were used as an aid in the selection of training fields. These training fields were used to compute class statistics for input to the classification program. Because of the difficulty in selecting field boundaries due to low contrast, several iterations of the training fields selected were required. Training fields for corn, rice, and bare soil were selected at random for available fields, while other training fields were selected on a field availability basis. Classification was performed on the Univac 1108 LARSYS, the ERIPS system, and on LARSYS on the Purdue terminal.

The results were not conclusive, which is probably attributable to the large variety of crop types. Analysis of the September 19, 1972, data pass showed corn, rice, and fallow land to be the most separable of the 17 classes. Only 8 of these 17 classes were selected for testing classification accuracy due to the limited representation of the remaining classes in the test site (table 4-XXVII).

Three classes had classification accuracies of less than 70 percent: corn, native trees, and weeds. The low classification of corn could be partially attributed to the weeds and drowned spots in fields which caused corn to be confused with pasture. Ten percent of the weedy corn (CORN) was classified into the category of good corn (CORN 1). Disregarding the misclassifications into pasture and CORN 1, corn had a classification accuracy of 84 percent. The low classification of weeds was confused with alfalfa and plum and almond trees. The similarity of weeds and alfalfa was somewhat understandable. However, the confusion of weeds with trees can only lead to the conclusion that information was needed in the ground-truth reports (fig. 3-14) to describe the density of the native trees. The five test ricefields had several distinct stages of growth which accounted for

TABLE 4-XXVII.- BUTTE COUNTY CLASSIFICATION PERFORMANCE SUMMARY

Group	No. of samples	Correct, %	Number of samples classified into -																
			Plums	Rice A	Corn	Fallow	Wheat S	Beans	Beets	Oats	Pasture	Alfalfa M	Alfalfa N	Grain sorghum	Sudan-grass	Native T	Weeds	Corn 1	Almonds
Training field performance																			
Plums	20	80.0	16	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1
Rice A	72	76.4	0	55	0	0	0	0	0	0	0	0	0	8	0	0	9	0	0
Rice A	60	53.3	0	32	0	0	28	0	0	0	0	0	0	0	0	0	0	0	0
Rice A	117	100	0	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice A	70	68.6	0	48	0	0	0	0	7	0	0	0	0	6	5	0	4	0	0
Rice A	144	58.3	0	84	0	0	0	0	4	0	17	6	0	2	0	0	31	0	0
Corn	110	66.4	0	2	73	0	0	0	0	0	10	5	1	0	0	5	0	10	4
Fallow	40	100	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	0
Fallow	21	95.2	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	1
Fallow	56	98.2	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	1
Wheat S	36	77.8	0	0	0	3	28	0	0	1	0	0	0	0	2	0	2	0	3
Beans	21	100	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0
Beets	20	75.0	3	0	0	0	0	0	15	0	1	0	0	0	0	0	0	0	2
Oats	8	100	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Pasture	36	72.2	1	0	0	0	0	0	0	0	26	4	3	0	0	0	1	0	1
Alfalfa M	25	88.0	0	0	0	0	0	0	0	0	2	22	0	0	0	1	0	0	0
Alfalfa N	16	81.3	0	0	0	0	0	0	0	0	3	0	13	0	0	0	0	0	0
Grain sorghum	16	75.0	0	1	0	0	0	0	0	0	0	0	0	12	3	0	0	0	0
Sudan-grass	9	100	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
Native T	12	58.3	1	0	0	0	0	0	0	0	1	0	0	0	0	7	0	1	2
Weeds	55	50.9	5	2	0	0	0	0	1	0	0	3	0	0	0	1	28	1	14
Corn 1	70	92.9	0	0	2	0	0	0	1	0	0	0	0	0	0	1	0	65	1
Almonds	20	95.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	19
Almonds	24	87.5	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	21
Total	1078		25	381	75	115	58	21	31	9	60	40	17	28	19	15	76	78	70
Overall performance (834/1,078) = 77.4																			
Test field performance																			
Plums	28	21.4	6	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0	14
Rice A	10	0.0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Rice A	99	92.9	0	92	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
Rice A	30	73.3	0	22	0	0	2	0	2	0	0	0	0	2	2	0	0	0	0
Rice A	25	72.0	0	18	0	0	0	0	2	0	0	0	0	4	1	0	0	0	0
Rice A	63	54.0	0	34	2	0	0	0	1	0	5	1	0	3	0	1	11	2	1
Corn	56	37.5	0	0	21	0	0	0	0	0	10	1	0	0	0	1	7	1	0
Fallow	91	94.5	0	0	1	86	0	0	0	0	0	0	0	0	0	2	3	0	0
Fallow	105	36.2	0	0	7	38	41	0	1	0	0	0	0	0	0	0	12	0	6
Wheat S	24	41.7	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	14
Beans	22	54.5	0	2	0	0	0	12	0	0	0	0	0	0	0	0	8	0	0
Corn 1	25	80.0	2	0	0	0	0	0	1	0	0	0	0	0	0	1	0	20	1
Corn 1	24	70.8	0	0	1	0	0	0	2	0	0	0	0	0	0	1	0	17	3
Almonds	25	60.0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	3	2	15
Total	647		8	168	37	124	81	12	13	0	35	4	0	16	3	8	38	44	58
Overall performance (391/647) = 60.4																			

the wide range of classification accuracy (0 to 92 percent). The zero classification was in a test field where harvesting had begun, and the field was classified as wheat stubble. The other test crops (plums, corn, beans, and almonds) had very low classification accuracies without readily apparent explanations.

4.2.6 Worth County

Approximately 30 percent of this 19-square-kilometer (12-sq.-mi.) study area was wooded. The cultivated fields in the site were generally small, ranging in size from less than 0.4 hectare (1 acre) to 40 hectares (100 acres). The majority of the fields were less than 12 hectares (30 acres). Field boundaries followed natural contours, woods, and drainage patterns, thus giving most of the fields a nonrectangular shape. Worth County was included in the analysis because it contained small and irregularly shaped fields of cotton, tobacco, and peanuts.

Using a clustering routine and DAS screening, clustering was attempted to assign homogeneous colors to fields of a known crop. From this method woods were delineated from cropland fairly well. A few of the crops, such as peanuts and bare soil, also separated fairly well. Corn and cotton seemed to be confused for each other; and other crops, especially the smaller fields, were not discriminable.

The printout of distances between clusters was examined in an attempt to ascertain which clusters were close and could be grouped to obtain more homogeneous field patterns. This technique was not successful; the best display output remained the initial one obtained by trial and error matching (fig. 4-37).

Table 4-XXVIII shows the values used in the filming and gives an indication of which clusters were grouped.

Five classes were selected using ERIPS: woods, corn, cotton, peanuts, and UNAMIT. The UNAMIT class was composed of areas that were usually found in the proximity of peanut fields, but appeared spectrally different from peanuts. The UNAMIT class was actually bare soil or harvested peanuts. Table 4-XXIX is a tabulation of the training and test fields used for ERIPS. These fields were selected because of their homogeneous appearance on the gray maps and clustering output, as well as appearing well defined. From the results of the classification, it appears that they were indeed clean fields. It probably would have been better to have had more training and test fields in each of the classes; however, the supply of well-defined fields was almost completely depleted by those selected. Figure 4-38 is the DAS output from ERIPS.

Using ERIPS for a finer breakdown, the woods class was divided into two classes, woods and SWOODS (sparse woods). Much of the southern portion of the study area was classified as corn. There were many small fields in this area, although not the abundance or corn that is shown. An area of sparse woods classified as corn was entered as a training field for SWOODS. Additional training and test fields were also added. It was hoped that the creation of this additional class would be sufficient to obtain a more accurate classification.

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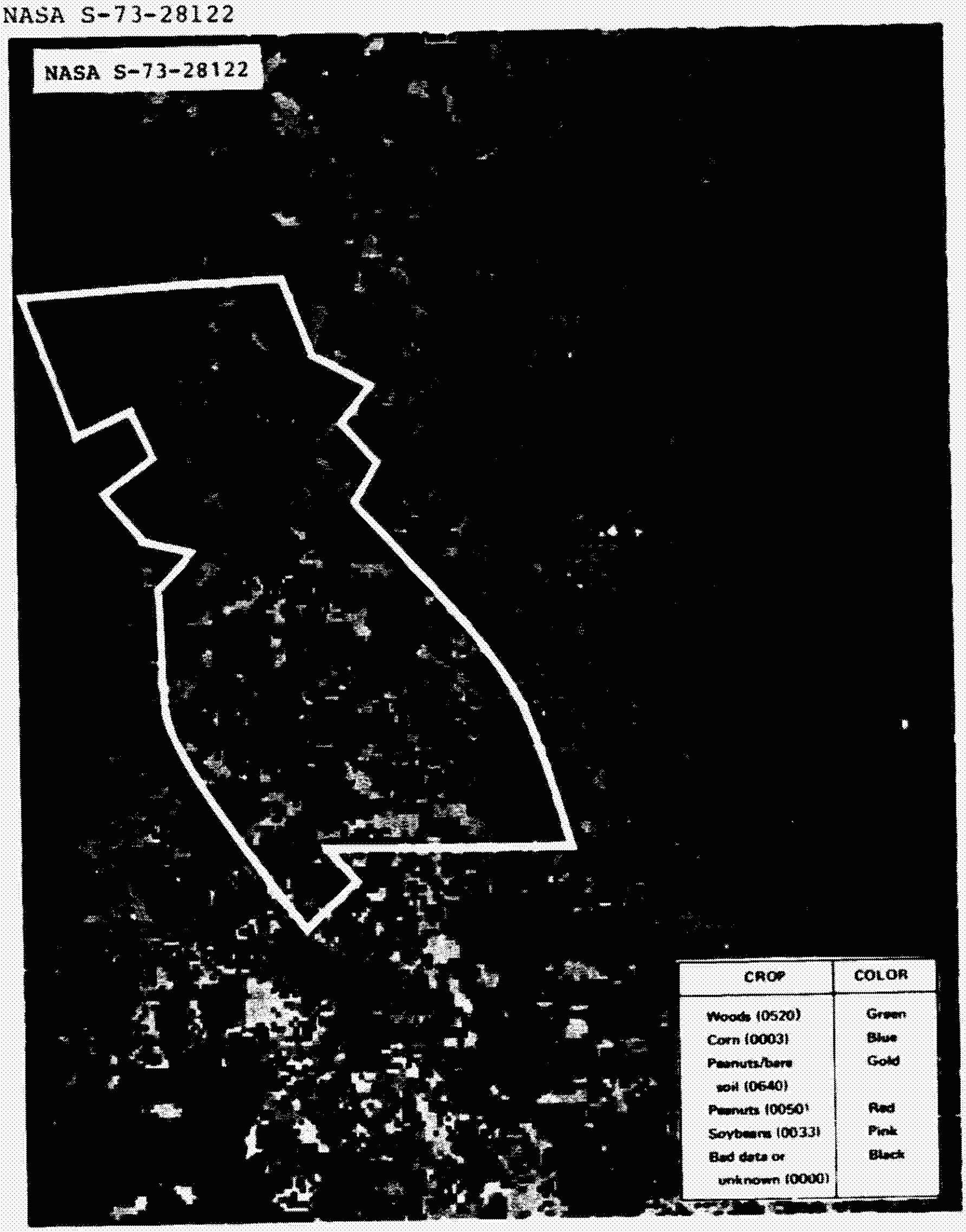

Figure 4-37.- Worth County DAS output from ISOCLS.

TABLE 4-XXVIII.- SUMMARY OF ISOCLS RUN

[Colors assigned: green (0520), blue (0003), gold (0640), red (0050), pink (0033), and black (0000)]

Cluster number	No. of points in cluster	Color assigned	Identification	Observations
1	615	0000		Spots along top edge of study
2	7969	0520 (brown)	Woods	
3	760	0000	Bad data	Diagonal lines
4	4890	0003 (blue)	Corn	
5	5869	0640 (gold)	Peanuts/bare soil	Peanuts probably
6	2885	0003 (blue)	Corn	
7	9374	0520 (green)	Woods	
8	600	0003 (blue)	Corn	
9	811	0003 (blue)	Corn	
10	1550	0520 (green)	Woods	
11	6674	0050	Peanuts	Possibly undug
12	6966	0033 (pink)	Soybeans	Probably harvested
13	261	0000	Bad data	Diagonal lines
14	8357	0520	Woods	
15	4	0000		Unknown
16	176	0520	Woods	
17	1241	0640	Peanuts/bare soil	
18	250	0000		Unknown

TABLE 4-XXIX.- TABULATION OF TRAINING AND TEST FIELDS FOR ER..PS RUN NUMBER 2

Type	No. of samples	Correct, %
Training fields		
Cotton 1	39	89.7
Cotton 2	26	84.6
Corn 1	63	98.4
Corn 2	28	82.1
Peanuts 1	36	80.6
Peanuts 6	20	100.0
UNAMIT 1	30	83.3
Woods 1	83	100.0
Woods 3	92	97.8
Test fields		
Cotton 4	24	41.7
Corn 3	29	62.1
Peanuts 3	15	80.0
UNAMIT	38	60.5
Woods 4	265	99.6
Woods 6	95	48.4
Woods 8	116	82.8

A few additional training and test fields were added to make the class a more adequate sample. Table 4-XXX lists the training and test fields used for figure 4-39. Training field corn 1 in figure 4-38 was intended to be identical to field corn 1 from figure 4-39; however, it classified poorly because it was erroneously entered.

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Figure 4-38.- DAS output from ERIPS run number 2 showing all classes.

TABLE 4-XXX.- TABULATION OF TRAINING AND TEST FIELDS FOR ERIPS RUN NUMBER 3

Type	No. of samples	Correct, %
Training fields		
Cotton 1	39	94.9
Cotton 2	32	90.6
Corn 1	127	66.9
Corn 2	35	94.3
Corn 3	25	92.0
Peanuts 1	54	98.1
Peanuts 2	28	78.6
Peanuts 4	32	96.9
SWOODS 1	104	92.3
Woods 1	119	97.5
Woods	92	93.5
PHAR 1	39	97.4
Test fields		
Cotton 3	34	94.1
Corn 4	23	73.9
Corn 5	27	77.8
Peanuts 6	20	100.0
SWOODS 2	53	64.2
Woods 4	260	99.6
PHAR 3	21	100.0

NASA S-73-28130

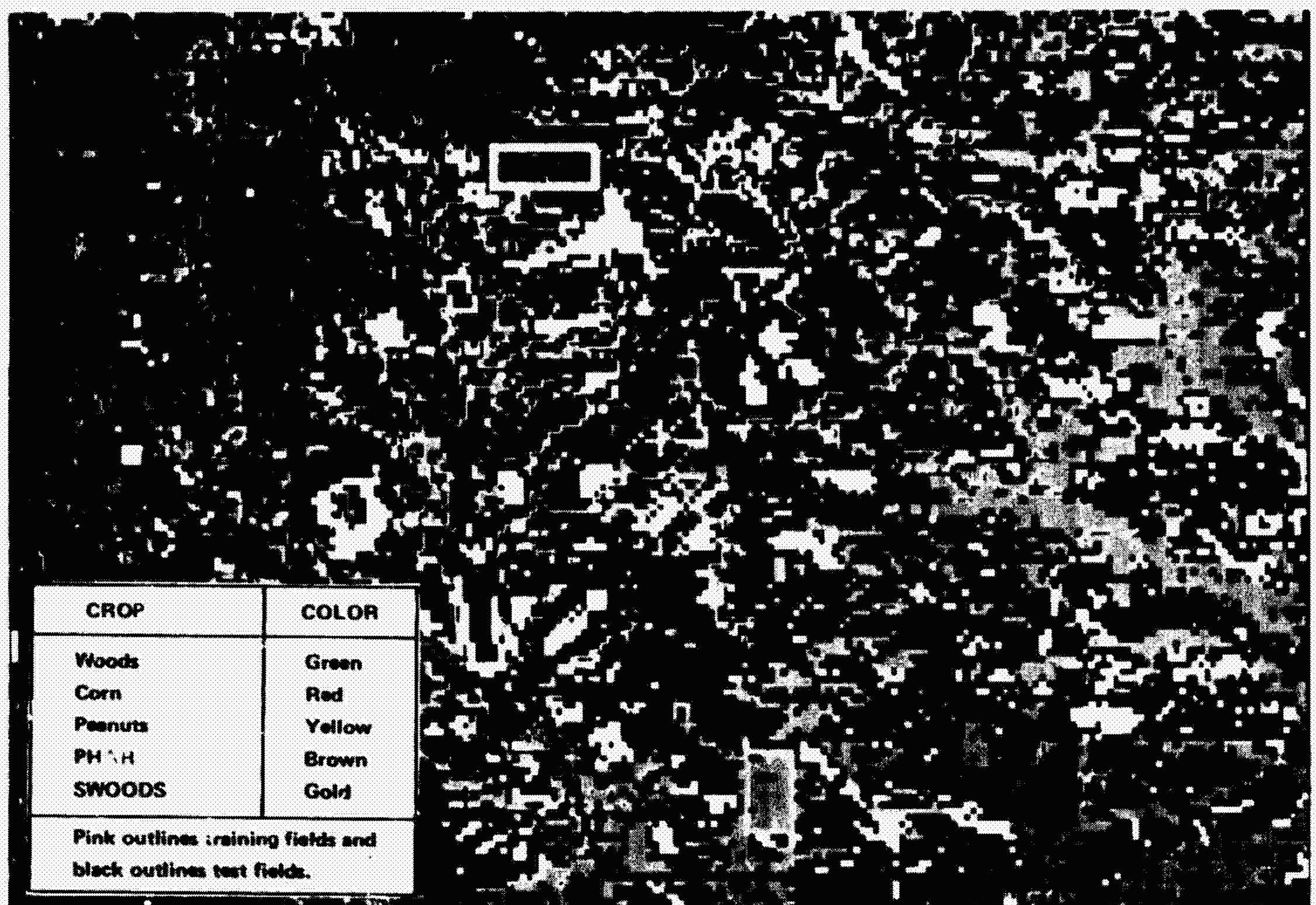

Figure 4-39.- DAS output from ERIPS run number 3 showing all classes.

5.0 CONCLUSIONS

A hierarchal approach was generally followed in this investigation. Agricultural areas were easily separated, and cropland within these areas was easily identified. These general separations were made primarily from spatial information obtained from the ERTS-1 data. The separation of crop types (i.e., small grains, truck farm crops, grasses, summer fallow) was accomplished by conventional interpretation, as well as by computer classification.

Conventional image interpretation was valid for Level I and Level II classification with at least 95-percent classification accuracy. Further breakdown into Levels III and IV was accomplished, but the accuracy was reduced considerably when an identification of individual species was attempted.

For image interpretation classification techniques, recombined false-color IR renditions were superior to all other additive false-color combinations. Image enhancement and image interpretation revealed that colors related more to the density of vegetative cover (crop maturity or crop condition) than to crop type or species.

Area measurement was performed on four of the study areas and boundary definition was the key to accurate field measurement. Many fields were too small or too narrow to be clearly defined. Rectangular fields, especially long, narrow ones with an orientation nearly parallel to the image scan lines, were difficult to define. Accurate boundary definition was also difficult at high-contrast borders, such as those between a field with low spectral response and a field with high spectral response. This situation caused a blooming effect, in which the field with high response appeared larger, and the field with low response appeared smaller. In Hill County, dimensions greater than 220 meters (722 ft) under optimum conditions of contrast and orientation were necessary for clear definition.

Field shape did not influence field measurement if satisfactory contrasting borders were present.

Area measurement using conventional image interpretation indicated that the standard error for fields with fair to good boundary definition was less than 5 percent on 5-hectare (12.5-acre) fields or larger.

Specific tracts were located by correlation to a UTM grid system. A technique was developed in which a UTM grid was overlaid on an ACVP enlarged image and matched to control points with known UTM coordinates. Slight variations in the scale of the enlarged image were compensated for by a family of grids, each varying slightly in scale. Matching the appropriate grid to the control points made possible the location of tracts in the 19-square-kilometer (12-sq-mi.) study areas to within approximately 200 meters (656 ft). This method is suitable for any test site covered by ERTS-1 for which large-scale base maps are available.

Computer classification of the ERTS-1 data was very successful for many important crops. Clustering maps and ERIPS displays with baseline photography and maps of the subject were the best tools for selecting training and test fields. Crop identification was accomplished to Levels III and IV in five of the test sites. Fields of less than 12 hectares (30 acres) were not easily identifiable. Worth County, Georgia, had many such small fields; and the classification results were very poor. The long, narrow test fields of Hill County produced rather poor classification accuracies (less than 70 percent). The smaller fields of Imperial County had an overall test-performance average of 78.7 percent. Hardin County, which has larger fields with rather poorly defined field boundaries, had a test field accuracy of 79.1 percent. Butte County, California, which had a variety of shapes and sizes, had an overall test field accuracy of 60.4 percent. Holt County (with large, well-defined fields) had a test field accuracy of 98 percent.

A general conclusion can be reached that only large (12 ha or more) well-defined fields should be considered for Level III and Level IV classification with the existing programs. However, for such fields Level III and Level IV classification of a wide variety of agricultural features can be obtained with reliable, repeatable accuracy.

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas, November 1974
641-14-07-50-72

APPENDIX A

GLOSSARY OF TERMS, ABBREVIATIONS, ACRONYMS, AND COMPUTER PROGRAMS

across-track

Across the direction of the spacecraft ground track; sometimes called horizontal when referring to output product coordinates.

ACV

Additive color viewer, a device enabling the color enhancement of one or more black-and-white images of the same scene by film density slicing and/or additive color procedures.

ACVP

Additive color viewer/printer, a photo-optical device which provides the capability to enlarge, superimpose, and register up to four separate black-and-white transparencies for viewing, printing, or color enhancement. (See appendix B.)

ADP

Automatic data processing, such as computer-aided computations.

along-track

In the direction of the spacecraft ground track; sometimes called vertical when referring to output product coordinates.

ASCS

Agricultural Stabilization and Conservation Service, an agency of the U.S. Department of Agriculture.

Block fallow

A farming practice where alternating blocks of land are cropped or fallowed.

BENDIX DAS

Bendix computer with color cathode-ray tube to display multispectral data tapes.

bpi

Bits per inch.

CCT

Computer-compatible tapes containing digital ERTS-1 data. These tapes are standard 19-centimeter (7-1/2-in.) wide magnetic tapes in 9-track or 7-track format. Four CCT's are required for the four-band multispectral digital data corresponding to one scene in the ERTS-1 images.

CED

County Executive Director. The Manager of the ASCS activity in each farming county.

CLASSIFY

Subsystem of LARSYS which classifies data into previously designated categories using the output from STAT.

clustering

Mathematical procedure for organizing multispectral data into spectrally homogeneous groups. Clusters require identification and interpretation in a post-processing analysis. Both ISOCLS and NSCLAS are spectral clustering programs.

contrast

Ratio of two adjacent scene radiances expressed as a number equal to or greater than 1.

CRT

Cathode-ray tube; television type screen.

DAS

Data analysis station, a computer system consisting of tape drives and computer, a display and control console, and film recorder. The DAS is used to reformat, analyze, and review remotely sensed digital data tapes.

Dell Foster Data Quantizer

Mechanical electronic planimeter. (See appendix B.)

DISPLAY

Subsystem of LARSYS which outputs the results of the classification runs.

EMBEDT

Univac 1108 program which was designed primarily to convert the ERTS system-corrected tape produced by Goddard Space Flight Center to multispectral data system edit format.

EOD

Earth Observations Division of the NASA Johnson Space Center, Houston, Texas.

EREP

Earth Resources Experiment Package consisting of the earth resources remote sensors mounted on the Skylab spacecraft.

ERIPS

Earth Resources Interactive Processing System, a system at JSC which allows real-time interaction by an investigator with several digital spectral analysis procedures. Major subsystems include pattern recognition by maximum likelihood classification, image registration, image composition, image manipulation and display.

ERTS-1

First Earth Resources Technology Satellite. ERTS-1 was launched into a circular, Sun-synchronous, near-polar orbit at an altitude of approximately 915 kilometers (494 n. mi.) in June 1972. It orbits the Earth 14 times a day and views the same scene every 18 days.

ERTS-1 scene

Collection of the image data of one nominal framing area (185 square kilometers) of the Earth's surface; this includes all data from each spectral band of each sensor.

Fallow

Land tilled but not seeded for one or more growing seasons to conserve moisture and kill weeds.

geometric accuracy

Geographic (latitude-longitude), based on the standard Earth-fixed coordinate reference system, which employs latitude and longitude.
Positional, the ability to locate a point in an image with respect to a map.

gray scale

A scale of gray tones between white and black, with an arbitrary number of segments. The ERTS-1 images have a 15-step gray scale exposed on every frame of imagery. The scale gives the relationship between gray level on the image and the electron beam density used to expose the original image.

ground-control point

Any point that has a known location on the Earth's surface which can be identified in ERTS imagery.

GSFC

Goddard Space Flight Center, National Aeronautics and Space Administration, located in Greenbelt, Maryland.

GSFC color composite

Color composite of three channels of ERTS-1 MSS digital data supplied to users by GSFC. They are third- or fourth-generation images as compared with first-generation composites produced from CCT's using a film recorder.

ha

Hectare, a metric unit of area equal to 10 000 square meters or 2.47 acres.

HATS

Houston Area Test Site encompassing 18 counties in southeast Texas. Houston is the primary urban area in the test site.

image skew

Image distortion caused when the scan of the sensor is not perpendicular to the plane formed by the spacecraft and the instantaneous ground-track velocity vector.

irradiance

Amount of energy impinging upon a unit normal surface, per unit time, per unit wavelength, per unit solid angle.

ISOCLS

Iterative Self-Organizing Clustering System, a computer program developed at JSC which utilizes a clustering algorithm to group homogeneous spectral data. Several controlling inputs allow investigators to control the size and number of clusters. Because the system produces a classification-type clustering map in which clusters require postprocessing identification and interpretation, the system is frequently referred to as a nonsupervised classification system.

ISODATA

Interactive Self-Organizing Data Analysis technique, a computer program for data clustering.

JSC

Lyndon B. Johnson Space Center, National Aeronautics and Space Administration, located in Houston, Texas.

λ

Lambda, the Greek symbol used to designate a wavelength of the electromagnetic spectrum.

LARS

Laboratory for Applications of Remote Sensing, Purdue University.

LARSYS

Name designating the set of classification programs developed for aircraft data handling and analysis at the Laboratory for the Applications of Remote Sensing (LARS) at Purdue University.

LARSYS II

Digital tape format for multispectral data used in LARSYS programs.

maximum likelihood ratio

Maximum likelihood ratio in remote sensing is a probability decision rule used to classify a target from multispectral data. Two types of errors are feasible; failure to classify the target correctly and misclassification of background as the target. In its simplest form, the likelihood ratio is P_t/P_b. This expression compares the probability (P) of an unknown spectral measurement being classified as target (t) to the probability of an unknown spectral measurement being classified as background (b). When $P_t/P_b \geq 1$, the formula decides t, and when P $P_t/P_b < 1$, it decides b. Probability density functions are computed from spectral samples, often referred to as training samples. As the number of training samples increase, the mathematical computations of the maximum likelihood ratio increase in complexity. As a result, digital computer analysis is required; and the entire process is referred to as automatic data processing (ADP) of multispectral remotely sensed data, or automatic spectral pattern recognition of multispectral remotely sensed data.

MCFV

Multiband camera film viewer is an electro-optical instrument designed to accept three channels of black-and-white positive or negative multiband negative transparencies, to register the images, and to display the composite image for color enhancement. Color enhancement is achieved through film density slicing and/or additive color viewing.

MSDS

Multispectral Data System tape format includes an aircraft 24-channel scanner and a ground data analysis station. The latter is one of the two major data analysis stations in the JSC-EOD Data Analysis Laboratory. (See DAS.)

MSS

Multispectral scanner system, sometimes referred to simply as the multispectral scanner. Usually refers to the operational scanning system on ERTS-1.

MTFO

Module training field option is a supervised computer-aided technique using the LARSYS classifier to allow modification of the statistical inputs.

multispectral scanner spectral bands

The division of the visible and near-IR portions of the electromagnetic spectrum into discrete segments.

MSS channel	ERTS-1 band	Wavelength, nm	Color
1	4	500-600	Green
2	5	600-700	Red
3	6	700-800	Reflective IR
4	7	800-1100	

n. mi.

Nautical mile, equivalent to 1/60th of a degree at the Earth's equator, or about 6076 feet.

nm

Nanometer, unit of length equal to 10^{-9} meters.

nonsupervised classification

A procedure which groups spectral data into homogeneous clusters. Identification and interpretation are achieved in a postprocessing analysis.

NSCLAS

The name of a clustering computer program developed by the Laboratory for the Application of Remote Sensing at Purdue University. (See clustering.)

PICTOUT

Subsystem to LARSYS which produces the alphanumeric pictorial printouts of data.

Pixel

Picture resolution element, refers to one instantaneous field of view (IFOV) as recorded by the multispectral scanning system. On the ERTS-1 system it is equivalent to approximately 0.44 hectare (1.09 acres). One ERTS-1 frame contains approximately 7.36×10^6 pixels, each described by four radiance values.

PMIS

Passive Microwave Imaging System.

PMIS DAS

SEL 810A computer with color CRT to display multispectral data tapes.

radiance

Measure of the radiant energy emitted by a radiator in a given direction.

RBV

Return beam vidicon.

reflectance

Ratio of the radiance of the energy reflected from a body to that incident upon it; commonly measured in percent.

SAPE

Sensor Application Performance Evaluation.

SC 4060

Used by the Univac 1108 to generate output on microfilm as opposed to the printer.

Scene-corrected data

System-corrected data that have been processed to produce precision located and corrected imagery on 24-centimeter (9-1/2-in.) film.

scene registration

Superimposing points in two images of a scene taken at the same time.

SCERTS

Univac 1108 program which outputs gray maps on microfilm.

SHNF

Sam Houston National Forest, located in the Houston Area Test Site.

spectral response

Spectral radiance of an object sensed at the satellite and recorded by the MSS.

STAT

Subsystem of LARSYS which generates and outputs statistics.

Strip fallow

Farming practice where alternating strips of land are cropped or fallowed to lessen wind or water erosion. The narrow strips are generally perpendicular to the prevailing wind direction.

Sun azimuth angle

Angle in degrees measured in the horizontal plane from true north to a vertical circle passing through the Sun.

Sun elevation angle

Angle of the Sun above the horizon measured in degrees.

supervised classification

Classification procedure in which data of known classes are used to establish the decision logic from which unknown data are assigned to the classes. The ADP supervised classification procedure utilized at JSC during the ERTS-1 project used a Gaussian maximum likelihood decision rule.

swath path

The dimension on the ground scene transverse to spacecraft velocity and within the sensor field of view (FOV).

system-corrected data

Film images generated by a data processing subsystem which makes initial radiometric and geometric corrections as the video-to-film conversion is recorded on 70-mm film through an electron beam recorder; formerly referred to as bulk images.

temporal data

Sequentially acquired information.

temporal registration

The ability to superimpose two images of the same scene taken at different times (same or different spectral bands).

test field

The spatial sample of digital data of a known ground feature selected by the investigator used to validate the statistical parameters generated from training field samples.

threshold

The boundary in spectral space beyond which a data point (pixel) has a sufficiently low probability of being included in a given class and, therefore, is purposely excluded from that class.

training field

The spatial sample of digital data of a known ground feature selected by the investigator, from which the spectral characteristics are computed for use in supervised multispectral classification of remotely sensed data. The statistics associated with training fields form the input to the maximum likelihood ratio computations and, in a sense, "train" the computer to discriminate between samples.

USDA

United States Department of Agriculture.

USGS

United States Geological Survey of the Department of the Interior.

UTM Grid

Universal Transverse Mercator grid; a rectangular coordinate system derived from a Transverse Mercator projection by which points or areas on the Earth's surface extending to 84° N. and 80° S. latitudes can be readily described and located within a unique quadrilateral area on a map. Precision processing of the ERTS-1 imagery corrects the imagery scene by scene so that its geographic orientation will conform to this UTM grid system.

APPENDIX B

EQUIPMENT UTILIZED

Additive Color Viewer/Printer (ACVP)

The ACVP is a photo-optical device which provides the investigator with the ability to enlarge, superimpose, and register up to four separate black-and-white transparencies for viewing, printing, or color enhancement. Each of the four optical channels is essentially an individual projector containing its own light source, vacuum platen, neutral density and selectable color filter, objective lens, and controls for X- and Y-movement, image rotation, focus, and magnification. The images from all channels are folded by two high-quality mirrors and converged onto a screen/printing plane.

The film gates accept up to 70-mm width roll or cut film, although only a 2.5-square-centimeter (1-sq.-in.) section is projected at a time. Each image is illuminated by a 300-watt tungsten bulb operating at a color temperature of 3200 K and projected onto a diffusing glass screen by a 210-mm focal length Schneider Componon lens. Each lens has its own mechanical shutter which is activated by a solenoid controlled from the front panel of the instrument. The tested resolution at the film gates exceeds 160 lines/mm, or better than 20 lines/mm at the viewing screen. The brightness of the projected image is controlled by a neutral density film roll at each channel which permits adjusting image brightness without changing the color temperature of the projection bulb. Red, green, blue, yellow, and cyan filters permit the construction of false-color enhancements. The filters are glass and are inserted between the condensing lens and the film gate.

Printing of the final image is accomplished at the viewing screen port using 20- by 25-centimeter (8- by 10-in.) or 10- by 13-centimeter (4- by 5-in.) cut film. Exposures are made by activating the appropriate shutters through an exposure button located on the front panel. Color or black-and-white film is used as required.

Multiband Camera Film Viewer (MCFV)

The MCFV is an electro-optical instrument designed to accept three channels of black-and-white positive or negative multiband camera film transparencies, to register the imagery, and to display the composite image for color enhancement. The output of the MCFV is a 30-square-centimeter (12-sq.-in.), 1000-line, television-type color display which is viewed by the investigator or photographed for later use. Input to the display is provided by the scanner section. This section consists of a three-channel flying-spot scanner and scanner film gates which accept either roll film up to 13 centimeters (5 in.) wide or cut film chips. The maximum area that may be viewed at one time, however, is limited to about a 56-mm square. Each film gate is provided with remotely controlled movements in the X,Y,Z scale and focus and rotation directions so that precision registration of the superimposed images may be achieved. All areas of a 13-centimeter (5-in.) frame are within reach with the appropriate X- and Y-movements. An electronic zoom is used to extend the magnification from about 5 times to about 30 times. A reference channel is also included to monitor light transmission through the system to compensate for transmission and excitation irregularities.

The processing electronics in the MCFV are comprised of the analog signal processor (ASP) and the digital image processors (DIP). The ASP processes the three data signals and the reference channel output. The processed signal is then sent to the display monitors for presentation. The monitors consist of three high-resolution monochrome television receiver units, one for each primary additive color. One monitor has a red phosphor screen, another has a green phosphor screen, and one has a blue phosphor screen. The three color images are combined through the use of two separate dichroic mirrors and precision placement of the monitors. When seen from the viewing port, a single image is seen which is capable of about 40 line pairs per mm resolution and with uniform color across the viewing screen. Controls are provided so that data from any or all channels may be sent to any or all of the monitors in any arrangement. In addition, the data may be presented to the monitors as positive, negative, or electronically reprocessed signals. Virtually any false-color combination can be obtained through this flexibility.

The signal from the scanner may be enhanced in a more quantitative mode through the use of the DIP. The DIP amplifies the data signal and slices it into 15 voltage levels; each level corresponding to a certain film density. The operator then programs a color into each level so that in the sliced image a color/film density relationship is set up. Each channel may be sliced and color programed independently and combined with any other channel. In this manner, film density differences may be greatly enhanced over that of conventional analog color techniques. The operator has the additional flexibility of being able to vary the width of the density (voltage) slice and to move the slice up and down the film density scale. Digital and analog displays may also be combined as desired.

A permanent record of the display is made by photographing the screen with a 70-mm Hasselblad camera and Ektachrome color film.

Dell Foster Graphic Quantizer

This instrument is essentially a combination mechanical/electronic planimeter. The perimeter of a field is manually traced by the operator while an electronic unit converts the movements into a digital readout of the area included within the completed perimeter trace. Readout is programed to indicate square inches on the film or as in this effort, the actual surface area in the scene. To achieve the latter, the scale of the print or transparency must be precisely determined and entered into the area program used by the data quantizer. Field areas are displayed to the tenths of an acre, which is considered within the tolerances of the instrument. Operator and image errors far exceed those of the instrument in any case. An average of five readings per field is normally made in order to minimize these errors. A teletype printout provides a permanent record of all measurements, plus any comment the operator wishes to add for future reference.

Earth Resources Interactive Processing System (ERIPS)

The Earth Resources Interactive Processing System (ERIPS) at JSC is a system combining software and hardware to allow for interactive analysis of remotely sensed data. The system is comprised of an IBM 360 Model 75 computer connected to two remote terminals. LARSYS software is used, but there are some JSC modifications and additions. It is designed to allow the analyst to analyze data from various remote sensor data, including the ERTS-1 MSS and Skylab EREP S-192 data. The primary applications available are image manipulation-registration and pattern recognition of digital multispectral data.

LARS Remote Terminal

The LARS Remote Terminal at JSC provides a direct communication link with the LARS at Purdue University. With this facility a user at JSC can have access to the most current LARS software for the processing of MSS data.

APPENDIX C

ERTS-1 TABLES FOR PROCESSING

TABLE C-I.- SCHEDULE OF DATA COLLECTION PASSES FOR 1972-1973

Orbit cycle (18 days)	Dates of coverage over each test site					
	Worth	Hill	Imperial	Hardin	Butte	Holt
1	8/3	8/8	8/8	8/12	8/13	8/16
2	8/21	8/26	8/26	8/30	8/31	9/3
3	9/8	9/13	9/13	9/17	9/18	9/21
4	9/26	10/1	10/1	10/5	10/6	10/9
5	10/14	10/19	10/19	10/23	10/24	10/27
6	11/1	11/6	11/6	11/10	11/11	11/14
7	11/19	11/24	11/24	11/28	11/30	12/2
8	12/7	12/12	12/12	12/15	12/17	12/20
9	12/25	12/30	12/30	1/3	1/4	1/7
10	1/12	1/17	1/17	1/21	1/22	1/25
11	1/30	2/4	2/4	2/8	2/9	2/12
12	2/17	2/22	2/22	2/26	2/27	3/2
13	3/7	3/12	3/12	3/16	3/17	3/20
14	3/25	3/30	3/30	4/3	4/4	4/7
15	4/12	4/17	4/17	4/21	4/22	4/25
16	4/30	5/5	5/5	5/9	5/10	5/13
17	5/18	5/23	5/23	5/27	5/28	5/31
18	6/5	6/10	6/10	6/14	6/15	6/18
19	6/23	6/28	6/28	7/2	7/3	7/6
20	7/8	7/16	7/16	7/20	7/21	7/24

TABLE C-II.- TABULATION OF THE TIME LAPSE BETWEEN ORDER AND RECEIPT FOR EACH TYPE OF DATA

County	Scene	Days
24-cm black-and-white transparency (standing order)		
Holt	1007-16551	179
Hill	1015-17392	98
Hardin	1021-16324	155
Imperial	1106-17504 1124-17504	87 101
Butte	1058-18221	118
Worth	1047-15382	129
24-cm color composite transparency (retrospective order)		
Holt	1007-16551	>239
Hill	1015-17392	57
Hardin	1021-16324	167
Imperial	1106-17504 1124-17504	90 94
Butte	1058-18221	148
Worth	1047-15382	148
Nine-track CCT (retrospective order)		
Holt	1007-16551	≈45
Hill	1015-17392	≈45
Hardin	1021-16324	≈45
Imperial	1106-17504 1124-17504	No record 21
Butte	1058-18221	No record
Worth	1047-15382	39

*For standing orders, the order date is considered to be the date the data were collected. For retrospective orders, the order date is considered to be the date on the order form.

TABLE C-III.- ERTS-1 DATA SUMMARY

Study Area: HILL CO., MONTANA

Observation Date	Observation Identifier	Type of Request *	Requested Bulk B&W 70mm Negative Trans	Requested Bulk B&W 70mm Positive Trans	Requested Bulk B&W 9.5 in. Positive Trans	Requested Bulk B&W 9.5 in. Positive Paper	Requested Bulk Color 9.5 in. Positive Trans	Requested Bulk Color 9.5 in. Positive Paper	Requested Bulk 9 Track Tape	Requested Precision B&W 9.5 in. Negative Trans	Requested Precision B&W 9.5 in. Positive Trans	Requested Precision B&W 9.5 in. Positive Paper	Requested Precision Color 9.5 in. Positive Trans	Requested Precision Color 9.5 in. Positive Paper	Requested Precision 9 Track Tape	Received Bulk B&W 70mm Negative Trans	Received Bulk B&W 70mm Positive Trans	Received Bulk B&W 9.5 in. Positive Trans	Received Bulk B&W 9.5 in. Positive Paper	Received Bulk Color 9.5 in. Positive Trans	Received Bulk Color 9.5 in. Positive Paper	Received Bulk 9 Track Tape	Received Precision B&W 9.5 in. Negative Trans	Received Precision B&W 9.5 in. Positive Trans	Received Precision B&W 9.5 in. Positive Paper	Received Precision Color 9.5 in. Positive Trans	Received Precision Color 9.5 in. Positive Paper	Received Precision 9 Track Tape	REMARKS
8-7-72	1015-17392	T	3	2	4		2	2	1	2	2		2	2	1	9	4	8		7	5	2	2	2		2	2	1	Good Image
10-18	1087-17400	S	2	1	2											2	1	2											Good Image
8-25	1033-17394	P	3	2	4		2	2	1	2	2		2	2	1	3	2	4				1		2		2	2		Study Area Clear
8-26	1034-17452	R	3	2	4		2	2	1								2	8				1							Clear
9-12	1051-17393	R	3	2	4		2	2	1									8		2	2	1			2				Clouds Over Study Area
9-13	1052-17452	R	3	2	4		2	2	1							6		4		2	2	1							Clear
9-30	1069-17393	S	2	1	2											2	1	2											Clear
10-1	1070-17452	S	2	1	2											2	1	2											Cloud Covered
10-18	1088-17452	S	2	1	2																								Std. Catalog indicates 0% Cloud

* S=Standing R=Data Request T=Telephone

TABLE C-III.- ERTS-1 DATA SUMMARY - Continued

Study Area: IMPERIAL CO., CALIF.

Observation Date	Observation Identifier	Type of Request*	Requested Bulk B&W 70mm Negative Trans	Requested Bulk B&W 70mm Positive Trans	Requested Bulk B&W 9.5 in. Positive Trans	Requested Bulk B&W 9.5 in. Positive Paper	Requested Bulk Color 9.5 in. Positive Trans	Requested Bulk Color 9.5 in. Positive Paper	Requested Bulk 9 Track Tape	Requested Precision B&W 9.5 in. Negative Trans	Requested Precision B&W 9.5 in. Positive Trans	Requested Precision B&W 9.5 in. Positive Paper	Requested Precision Color 9.5 in. Positive Trans	Requested Precision Color 9.5 in. Positive Paper	Requested Precision 9 Track Tape	Received Bulk B&W 70mm Negative Trans	Received Bulk B&W 70mm Positive Trans	Received Bulk B&W 9.5 in. Positive Trans	Received Bulk B&W 9.5 in. Positive Paper	Received Bulk Color 9.5 in. Positive Trans	Received Bulk Color 9.5 in. Positive Paper	Received Bulk 9 Track Tape	Received Precision B&W 9.5 in. Negative Trans	Received Precision B&W 9.5 in. Positive Trans	Received Precision B&W 9.5 in. Positive Paper	Received Precision Color 9.5 in. Positive Trans	Received Precision Color 9.5 in. Positive Paper	Received Precision 9 Track Tape	REMARKS
8-25-72	1033-17441	P	3	2	4		2	2	1	2	2		2	2	1	3	4	4		2		1		2			2	1	Good Image
8-26	1034-17500	P	3	2	4		2	2	1							4	2	4				1							Good Image
9-13	1052-17495	R	3	2	4		2	2	1							5	2			2		1							Cloud Free
10-1	1070-17596	S	2	1	2											2	1	2											Clear
11-5	1105-17445	S	2	1	2		3	3	1				3	3	1		1	2		3	3	1				3	2	1	Good Image
11-6	1106-17504	S	2	1	2		2	2	1	2	2		2	2	1	5	1	5		5	2	2	2	6		4	5	1	Cloud Free
11-23	1123-17450	S	2	1	2											2	1	2											Study Area Clear
12-11	1141-17450	S	2	1	2											2	1	2											Cloud Covered
12-12	1142-17504	S	2	1	2											2	1	2											Clear
11-24	1124-17504	S	2	1	2		2	2	1	2	2		2	2	1	2	1	4		2	2	1							Clear
12-29	1159-17445	S	2	1	2											2	1	2											Clear
12-30	1160-17503	S	2	1	2											2	1	2											Clear

* S=Standing R=Data Request T=Telephone

ORIGINAL PAGE IS OF POOR QUALITY

TABLE C-III.- ERTS-1 DATA SUMMARY - Concluded

Study Area:

HOLT CO., NEBRASKA

Coverage Date	Observation Identifier	Type of Request *	REQUESTED													RECEIVED													REMARKS
			Bulk							Precision						Bulk							Precision						
			B&W				Color			B&W			Color			B&W				Color			B&W			Color			
			70mm		9.5 in.		9.5 in.			9.5 in.			9.5 in.			70mm		9.5 in.		9.5 in.			9.5 in.			9.5 in.			
			Negative Trans	Positive Trans	Positive Trans	Positive Paper	Positive Trans	Positive Paper	9 Track Tape	Negative Trans	Positive Trans	Positive Paper	Positive Trans	Positive Paper	9 Track Tape	Negative Trans	Positive Trans	Positive Trans	Positive Paper	Positive Trans	Positive Paper	9 Track Tape	Negative Trans	Positive Trans	Positive Paper	Positive Trans	Positive Paper	9 Track Tape	
7-29-72	1006-16493	T	3	2	4		2	2	1								2	4				1							Cloud Free
7-30	1007-16551	T	3	2	4		2	2	1	2	2		2	2	1		2	4			3	1		2		2	2	1	Cloud Free
8-16	1024-16495	T	3	2	4		2	2	1							3	2	4				1							Cloud Free
8-16	1024-16500	T	3	2	4		2	2	1	2	2		2	2	1	3	2	4		2		1	2	4		1	2	1	Cloud Free
9-21	1060-16494	R	3	2	4		2	2	1							3	2	4		2	2	1							Cloud Free
9-22	1061-16552	R	3	2	4		2	2	1							3	4	4			1	1							Cloud Free
10-9	1078-16495	S	2	1	1											2	1	1											Cloud Covered
10-28	1097-16555	S	2	1	1											2	1	1											Cloud Covered
12-2	1132-16503	S	2	1	1											2	1	1											100% Clouds
12-3	1133-16561	S	2	1	1											2	1	1											Cloud Covered
12-21	1151-16561	S	2	1	1											2	1	1											Cloud Covered

* S=Standing R=Data Request T=Telephone

TABLE C-IV.- ERTS-1 SUMMARY OF DATA COLLECTED BEFORE MARCH 1, 1973[a]

Condition	Holt Co.	Hill Co.	Hardin Co.	Butte Co.	Imperial Co.	Worth Co.
Total days over site	12	14	14	16	14	14
Total days data collected	12	13	13	14	13	12
Usable data cycles received at JSC	3	4	1	7	5	3
Total data sets received at JSC	10	8	7	14	12	6
Data sets 0% cloud not received	1	0	0	0	2	0
% usable data received at JSC	33	50	14	50	42	50
Data sets not in standard catalog	2	6	2	0	1	2
Data 10 to 40% clouds not received	1	0	0	0	1	5
Data 40 to 80% clouds not received	1	0	1	0	0	0
% total data usable	33	31	8	50	54	25
% total probable data (<40% clouds)	42	31	8	50	62	66

[a]Usable % data received at JSC - 57 received, 23 usable = 40%. Usable % of total data collected - 77 collected, 26 usable = 34%.

TABLE C-V.- GROUND-TRUTH DATA COLLECTION FORM

William J. Crea, Jr.
Earth Observations Div. - TF2
NASA-MSC
Houston, Texas 77058

ERTS-A/ASCS

GROUND OBSERVATION SUMMARY FOR ________
Date

County (1) ____________ OBSERVATION ________ (annual = 1; periodic = 2)

No. 3-6	Farm No. 7-16	Field No. 17-26	Acreage 27-29	Crop 30-44	Est. Crop Height 45-48	Stage of Maturity 49-65	Row Dir. 65	Observation 66-80

County

1. Holt-Nebraska
2. Hill-Montana
3. Hardin-Iowa
4. Imperial-California
5. Butte-California
6. Worth-Georgia

Row Direction

0. Not Applicable
1. NS
2. EW
3. NW-SE
4. SW-NE
5. Contour

Observations
(Four Choices, Max.)

0. None
1. Lodging
2. Drought
3. Extremely woody
4. Insect damage
5. Hail damage
6. Plant disease
7. Nutrient deficiency
8. Harvested
9. Tillage after harvest
10. Drowned spots
11. Thin stand
12. Bare soil
13. Crop cultivation
14. ____________
15. ____________

TABLE C-VI.- HILL COUNTY, MONTANA, AREA MEASUREMENT

[Width of rectangular fields]

Farm no.	Field no.	Width, meters	Farm no.	Field no.	Width, meters
N-1	1	72.42		18	88.51
	2	40.23		19	82.47
	3	74.43		20	100.58
	4	66.38		21	84.49
	5	68.39		22	92.53
	6	84.49		23	--
	7	46.25		24	--
	8	30.17		25	--
	9	76.44		26	--
	10	--	N-3	1	--
N-2	1	116.67		2	--
	2	68.39		3	--
	3	--		4	--
	4	--		5	--
	5	265.54		6	100.58
	6	--		7	100.58
	7	156.91		8	297.72
	8	--		9	102.59
N-21	1	52.30		10	94.54
	2	52.30		11	112.65
	3	52.30		12	--
	4	48.28	N-4	1	92.53
	5	50.29		2	116.67
	6	52.30		3	86.50
	7	52.30		4	116.67
	8	52.30		5	100.58
	9	88.51		6	110.64
	10	44.25		7	108.63
	10b	36.21		8	108.63
	11	80.46		9	96.56
	12	86.50		10	104.60
	13	64.37		11	96.56
	14	82.47		12	88.51
	15	--		13	164.95
	16	--		14	9[illegible].56
	17	95.56		15	207.20

TABLE C-VI.- HILL COUNTY, MONTANA, AREA MEASUREMENT - Continued

[Width of rectangular fields]

Farm no.	Field no.	Width, meters
	16	--
	17	--
	18	--
	19	164.95
	20	96.56
	21	96.56
	22	96.56
	23	110.64
	24	152.88
	25	102.59
	26	80.46
	27	104.60
	28	126.73
	29	106.61
	30	106.61
	31	--
	32	--
	33	116.67
	34	--
	35	--
	36	--
N-16	1	--
	2	--
	3	--
N-17	1	--
	2	--
	3	--
	4	106.61
	5	106.61
N-18	1	--
	2	--
	3	80.46
	4	80.46
	5	80.46
	6	84.49
	7	76.44
	8	86.50
	9	94.54
	10	82.47

Farm no.	Field no.	Width, meters
N-19	1	--
	2	--
	3	--
	4	--
	5	--
	6	--
	7	--
N-20	1	275.60
	2	--
	3	--
N-5	1	205.19
	2	201.16
	3	209.21
	4	197.14
N-6	1	164.95
	2	422.45
	3	221.28
N-7	1	112.65
	2	102.59
	3	112.65
	4	102.59
	5	102.59
	6	102.59
	7	90.59
	8	--
	9	--
	10	108.63
	11	--
	12	--
N-8	1	144.84
	2	301.75
	3	241.40
	4	277.61
	5	418.42
	6	126.73
	7	110.64

TABLE C-VI.- HILL COUNTY, MONTANA, AREA MEASUREMENT - Concluded

[Width of rectangular fields]

Farm no.	Field no.	Width, meters	Farm no.	Field no.	Width, meters
N-13	1	62.36	N-9	1	261.51
	2	102.59		2	221.28
	3	102.59		3	--
	4	128.74		4	--
	5	102.59		5	80.46
	6	104.60		6	88.51
	7	88.51		7	88.51
	8	132.77		8	100.58
	9	--		9	52.30
	10	--		10	--
	11	--		11	--
	12	--		12	--
	13	96.56		13	--
	14	100.58		14	88.51
	15	100.58		15	--
	16	100.58		16	--
	17	116.67		17	--
N-12	1	366.12		18	--
	2	438.58	N-10	1	--
	3	--		2	--
	4	124.72		3	80.46
N-14	1	201.16		4	--
	2	394.28		5	--
	3	213.23		6	--
N-15	1	--		7	--
	2	--		8	--
	3	--	N-11	1	466.70
	4	120.70		2	341.98
	5	104.60			
	6	92.53			
	7	104.60			
	8	96.56			
	9	96.56			
	10	100.58			
	11	100.58			
	12	--			
	13	--			

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