https://ntrs.nasa.gov/search.jsp?R=19710024899 2019-04-29T09:35:14+00:00Z

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

INTERAGENCY REPORT USGS-183

A SYSTEM OF REGIONAL AGRICULTURAL LAND USE MAPPING TESTED AGAINST SMALL SCALE APOLLO 9 COLOR INFRARED PHOTOGRAPHY OF THE IMPERIAL VALLEY (CALIFORNIA)

by
Claude W. Johnson
Leonard W. Bowden
Robert W. Pease
Department of Geography
University of California
Riverside, California

November 1969

Prepared by the U.S. Geological Survey (USGS) for the National Aeronautics and Space Administration (NASA) under NASA Contract No. W-12570, Task No. 160-75-01-32-10. Work performed by the University of California for the USGS Geographic Applications Program under USGS Contract No. 14-08-0001-10674. **This report will not be resubmitted to NTIS by NASA.**

Plate 1

Color infrared (CIR) photograph of the Imperial Valley with field pattern map overprint. The photo was taken from the Apollo 9 earth orbiting satellite on March 12, 1969 from an altitude of 150± miles (241.5 km). (Taken with a Hasselblad camera with 80 mm focal length lens using a Wratten 15 filter). The print is a 12 times enlargement from the original. The problem of rectifying an orthographic photo to a polyconic map projection can be seen by the out-of-register area in the upper right corner. The Apollo 9 CIR photo was used to test the agricultural land use interpretation and analysis system described in this paper.

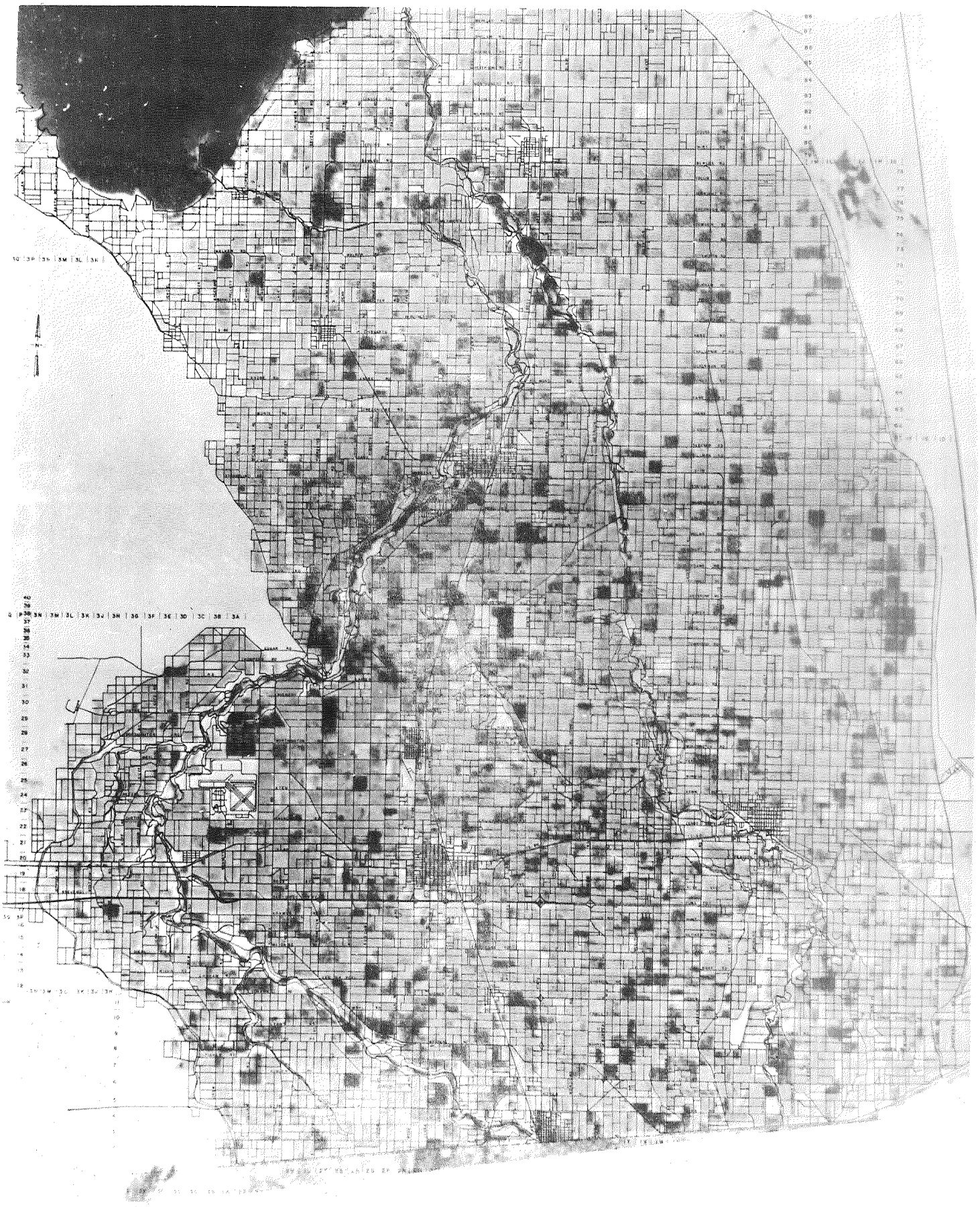


TABLE OF CONTENTS

Plate I . . . . . *i*

Table of Contents . . . . . *ii-v*

Abstract. . . . . *vi*

I Introduction 1

A. Objective 2

B. Study Areas 2

II Data Source and Technical Evaluation 4

A. Image Resolution 4

B. Image Quality 6

III Analysis of Crop Color Variations Recorded on CIR Imagery. 9

A. Changes in Color Response Related to Season 10

1. Effects of Differences in Crop Maturity 10

2. Effects of Soil Exposure 11

3. Influences of Farming Practices 11

4. Effects of Crop Shading on Amount of Background Infrared Illuminance 12

B. Variations of Crop Color on CIR Imagery with Changes in Resolution 13

IV Design of Agricultural Land Use Interpretation and Mapping Systems 15

A. Crop Signature Tables 16

1. Color Signatures 17

2. Environmental Factors 18

a. Physical Factors 18

b. Cultural-Economic Factors 20

3. Farming Patterns 20

TABLE OF CONTENTS (Contd)

B. Worldwide Agricultural Land Use Code 22

1. Requirements 23

2. A User Oriented Land Use Code 23

3. Hierarchical Five Digit Level Code 25

C. Design and Preparation of Local Base Maps 27

1. Selection and Use of Control Map 27

2. Adaptation of Coordinate Systems 28

a. Geographical Coordinate System Modification . . 28

b. Local Grid System 30

V Correlation of Photographic Interpretation with Actual Ground Data 32

A. Assumptions and Methods of Correlation 32

1. A priori Knowledge of Test Site Area 32

2. Ground Surveys for Correlation Studies 33

3. Representative Selection of Survey Data 34

B. Correlation of Apollo 9 Crop Identification with Ground Survey Data 35

1. Specific Crop Identification (Fifth Digit Level). . 37

2. Primary Agricultural Class Categorization (Third Digit Level) 38

3. Agricultural Land Use Not Identifiable or Not Detected 39

C. Correlation of Apollo 9 Crop Acreage Summary with Reported Crop Acreage 39

1. Specific Crop Type Acreage 40

2. Primary Agricultural Class Acreage 44

3. Total Cultivated and Available Cropland Acreage . . 45

D. Cosistancy of Error Between Correlations 45

TABLE OF CONTENTS (Contd)

VI Conclusion 47

Bibliography. 49

Appendix A Description of Imperial Valley. 50

1. Geographical 50

2. Climate 51

Appendix B Interpretation, Mapping, and Analysis Procedures . . . 55

1. Base Map Preparation 56

2. Development of Crop Calendar for the Date of the Imagery 56

3. Image Projection or Base Map Overlay or Overprint . 56

4. Establishing Crop Color Signatures from Ground Survey Data 59

5. Determine and Record Individual Field Unit Location 59

6. Determine and Record Individual Field Unit Color on CIR Image 60

7. Perform Computer Crop Identification 60

8. Prepare Final Agricultural Land Use Map and Statistical Data 62

Appendix C

1. Crop Calendar for the Imperial Valley 63

2. Worldwide Agricultural Land Use Code 64-75

3. Agricultural Land Use Map of Imperial Valley . . . 76

4. Ground Survey Routes for Apollo 9 Correlation Studies 77

Appendix D Thematic Land Use Maps of the Imperial Valley From March 12, 1969 Apollo 9 Photography 78-94

Table I Source of Imagery (Imperial Valley) 5

Table II Correlation of Apollo 9 Land Use Identification with Ground Survey Data 36

TABLE OF CONTENTS (Contd)

Table III Analysis of Errors on Field Crop Identification. 37

Table IV Summary of Correlation Between Reported and Detected . .41-43

Table V Comparison of Errors of Selected Field Crops 46

Table VI-1 Climatic Data for the Imperial Valley. 52

Table VI-2 Climatic Data for the Imperial Valley. 53

Table VII List of Major Crops Under Cultivation on March 12 (Imperial Valley). 57

Figure 1 Sensitometry of SO-180 Color Infrared Film Used in the Apollo 9 Photography 8

Plate 1 Apollo 9 Imperial Valley CIR Photo with Map Overprint. . . *i*

Plate 2 Example of 7 Crop Colors Recorded on CIR Imagery 95

Plate 3 Example of Alfalfa Field in 3 Stages of Cutting with 3 Colors 95

Plate 4 Example of Six Different Alfalfa Fields in Different Stages of Maturity 95

Plate 5 Example of Two Different Crops Showing the Same Color. . . 95

Plate 6 Example of Sugar Beet Field at High Resolution 96

Plate 7 Example of Same Sugar Beet Field at Medium Resolution. . . 96

Plate 8 Example of Sugar Beet Field After Harvest 96

Plate 9 Ground CIR Photo of Sugar Beets Showing Background Difference 96

ABSTRACT

Interpretation results of the small scale CIR photography of the Imperial Valley (California) taken on March 12, 1969 by the Apollo 9 earth orbiting satellite have shown that world wide agricultural land use mapping can be accomplished from satellite CIR imagery if sufficient a priori information is available for the region being mapped. Correlation of results with actual data is encouraging although the accuracy of identification of specific crops from the single image is poor. The poor results can be partly attributed to only one image taken during mid-season when the three major crops were reflecting approximately the same and their CIR image appears to indicate the same crop type. However, some incapacity can be attributed to lack of understanding of the subtle variations of visual and infrared color reflectance of vegetation and surrounding environment. Analysis of integrated color variations of the vegetation and background environment recorded on CIR imagery is discussed.

Problems associated with the color variations may be overcome by development of a semi-automatic processing system which considers individual field units or cells. Deisgn criteria for semi-automatic processing system are outlined.

Section I

Introduction

Studies using color infrared (CIR) photography of the Imperial Valley (California) at several different scales and ground resolutions have produced three equally important conclusions on the development of agricultural land use photo interpretation systems. The results are summarized as follows:

1. Definitive agricultural land use mapping of a very large region can be accomplished from interpretation of small scale CIR satellite photography. Analysis utilizing the unit record system described below has shown a capability to define and classify a unit as small as 10 acres (4^+ hectares). Results show that the accuracy of interpretation based upon crop CIR color signature from small scale imagery is dependent upon availability of a priori information of the region, detection of other identification factors on the image, and the careful selection of dates of sequential CIR imagery.

2. The ability to identify agricultural crops on small scale imagery can be attributed, in part, to predictable color variations occuring among crop types. These variations, however, are also seasonally related which introduces another set of variables that makes color signatures inconsistent. This creates identification problems when color comparisons are being made between known and unknown examples of the same crop on the same image. Considerable analysis, is still required before automatic equipment can be programmed to detect the subtle variations occuring within the same crop type.

Additional variations in crop color are created by technical problems of film quality control, variabilities at time of exposure, storage history of the film before processing, and the processing itself. These latter variations cause differences to appear between films of different coating batches rather than on images contained within the same film roll.

3. A method for overcoming problems being encountered due to variations of the crop image color is to design semi-automatic processing systems to utilize data recorded on the image, and to employ previously acquired data. The system designed in this study requires that each field unit or cell on the image be examined individually to determine color record, location, and any other data present. Referral is then made by the computer to previously stored data of that field and region to assist in final identification. It should be noted that efficient processing of sequential photography will require a system of individual unit or cell comparison if agriculture is to be analyzed. Maintaining field unit records enhances the ability to perform special regional agricultural analysis and distribution studies as well as to simplify preparation of regional agricultural land use maps or summaries. (Table IV, Appendix D)

A. Objective

The study emphasizes the design and development of a computer oriented agricultural land use mapping system. However, the role that the crop color and tone variations play, especially on small scale CIR imagery, requires considerable analysis be made of the many variations that occur when recording agricultural crops on CIR film. Of necessity the analysis of crop color variations will precede the description of the design and development of an agricultural land use mapping system. Testing of the system with the small scale Apollo 9 CIR imagery of the Imperial Valley concludes the report.

B. Study Area

Selection of the study area was predetermined by: (1) available imagery; (2) the high probability of obtaining future satellite imagery; (3) a need for

an area with considerable diversification of agricultural crop types; and (4) accessibility of the area to the investigators to enable frequent ground and/or field surveys to verify and/or correct results being obtained.

Two areas met the established requirements: (1) The Coachella Valley centered around Indio, California, and (2) the Imperial Valley between the Salton Sea and the California-Mexican border. The first is dominated by tree crops (citrus and dates) and grapes. A review of the annual crop reports of the Imperial Valley Irrigation District shows that there are 48 different types of crops normally grown in the Imperial Valley. Of these 48 crop types there are 34 which are reported as having more than 100 acres (40^{+} hectares) under cultivation annually and of these latter 34 crop types there are 18 crops which may be considered as the major crops since they are reported as having more than 1000 acres (404.7 hectares) under cultivation annually. In addition, the Imperial Valley contains more than 100 cattle feed lots and supports most of Southern California's production of beef cattle. Of the two, the Imperial Valley was selected as the area of study because the closer Coachella Valley, with its more permanent crop types, had already been mapped, one of the experimental goals of the project, but complete mapping of the Imperial Valley was not as yet accomplished. A description of the geography and the climate of the Imperial Valley may be found in Appendix A.

Section II

Date Source and Technical Evaluation

Table I outlines the source of imagery used to conduct this study. High and medium scale photography was obtained by the NASA Mission 73 flights conducted over the Southern California Test Site 130. The small scale satellite imagery was obtained by the Apollo 9 earth orbiting satellite.

A. Image Resolution

Preparation of the base map was made primarily from the June 11, 1968 imagery with a nominal ground resolution of 1.3 feet (40 cm) at a scale of 1:16,000. While this scale on the 9 inch (23 cm) format proved to be a workable image for hand mapping, the 1:4,000 scale image taken by the NASA mission 73 flight on May 21, 1968 was too large to map efficiently at the 1:62,500 scale. The latter imagery was also too large to provide useful comparison between crop types because quite often only a portion of a single field crop appeared on the 9 inch format. Each frame at the latter scale covered little more than a quarter section (160 acres, 64 hectares) and experience has shown visual interpretation can best be accomplished with at least ten different fields with several crop types appearing in the same exposure. The fine resolution (often as detailed as 4 inches or 10 cm) does permit close inspection of the cultural features and farm management practices, and provides confirmation of details that are not as obvious on smaller scale imagery, but it provided scanty readability of crop color tones. The inadequate readability was caused by separation of the signature inputs (vegetation and visible soil) that combine to make the normal crop color seen in medium and small scale imagery.

TABLE I SOURCE OF IMAGERY - (IMPERIAL VALLEY)

Date	% Cover	Originating Agency*	Platform	Altitude (feet)	Sensor	Focal Length (mm)	Filter Combination	Shutter f-stop	Shutter Speed	Nominal Resolution (meter)	Nominal Resolution (ft.)	Scale
13 May 68	11	WAS	Apache	10,000	T-11	254	WR15+80B	f-5	1/200	0.25	0.82	1:10,000
13 May 68	1	UCR(WAS)	Apache	10,000	35mm	50	WR15+80B	f-6	1/200	1.52	5.00	1:63,000
21 May 68	11	NASA/USGS	CV240A	2,000	RC-8	153	WR15	f-6.8	1/350	0.10	0.33	1:4,000
11 June 68	60	WAS	Apache	16,000	T-11	254	WR15+80B	f-8	1/250	0.40	1.30	1:16,000
8 Mar 69	6	UCR	Cherokee	10,000	35mm	50	WR15+80B	f-8	1/250	1.52	5.00	1:63,000
8 Mar 69	30	UCR	Cml 727	40,000	35mm	50	WR15+80B(80C)	f-8	1/250	7.60	25.00	1:250,000
12 Mar 69	100	NASA	Apollo 9	792,000	Hasselblad	80	WR15	f-8	1/250	80.00	230.00	1:3million
10 May 69	0.5	UCR	Cherokee	10,000	35mm	50	WR15+80B	f-8	1/250	1.52	5.00	1:63,000

* WAS = Western Aerial Survey, Inc. of Riverside
UCR = University of California, Riverside faculty and investigators using handheld cameras in private aircraft or commercial airliners.

B. Image Quality

Technical evaluation of the CIR film used in the 1968 missions has been discussed by Bowden in "Mission 73 Summary and Data Catalog", Technical Letter NASA 132. It is noted again that the recommended W80B filter was used in combination with the W15 filter on certain flights to equalize the yellow and magenta dye layers in the film in order to prevent predominance of cyan in the image. (Pease, Bowden, 1969). The May 13 imagery was overexposed. From this and other experiments it has been found that a shutter setting of f-8 at a speed of 1/250th of a second is a suitable setting for 8443 film using 15 + 80B filters under normal lighting conditions (high sun angle) in desert environment of Southern California. Compensation should be made for abnormal conditions such as low sun angle or large expanses of white sand. CIR photography made with 35 mm handheld cameras at 10 and 20 thousand feet have also yielded valuable information. These are near obliques with resolution sufficient to perform most types of agricultural land use studies. The small expense of both film and platform for 35 mm flights is a significant consideration when planning repeated aerial surveys for studies needing time-lapsed imagery.

The Apollo 9 imagery, taken with only a w 15 filter, was found to be atypical CIR film on postflight inspection. The magenta dye-forming layer had a lower than usual gamma which with the EA-4 processing performed by the Manned Spacecraft Center, was lower in sensitivity than the cyan layer at densities below 0.8. Fortunately, for crop targets, this equalized layer sensitivities with only the Wratten 15 filter. This negated the cyan

color balance that frequently ensues from airluminance which from high altitudes destroys the red of many vegetation targets. Figure 1 graphically indicates the difference between the sensitometry of the Apollo 9 (SO - 180) film and normal type 8443 CIR film, processed in both the recommended Kodak E-3 chemicals and the EA-4 used. (Pease 1969). This is but one example of the problems produced by the several variables which exist with the use of CIR imagery.

If interpretation systems are to depend on color as a crop signature, more stringent quality control must be instituted in all steps of the system to reduce the variables. The current inclusion by MSC of a step wedge or "frisket" prior to and after each series of exposures is helpful in noting variations in film, exposure, and processing. This is important since several days may elapse between exposure and processing. Ideally a standard ground target should also be exposed at the start of each series, but this becomes impractical for satellite photographs. In the absence of such a ground target, an available reference may be a black-top surface such as a highway or parking lot which is essentially neutral or a soil surface of known reflectance may also be used as a neutral target.[1]

---

[1] Further discussion may be found in Egan, 1969.

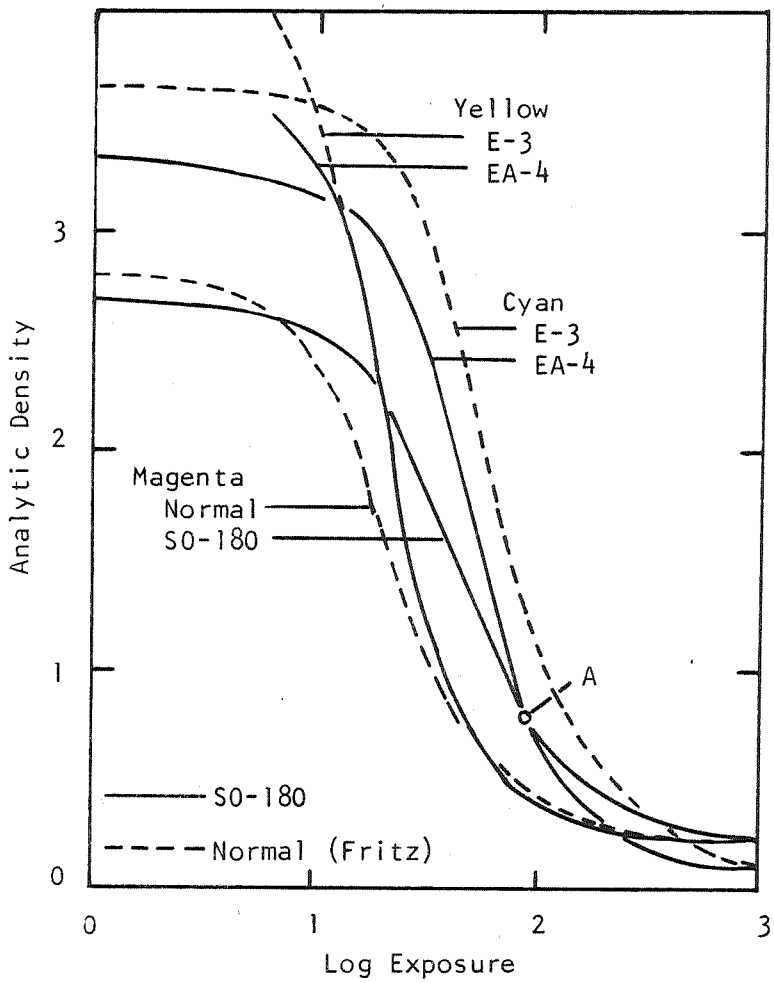


Figure 1. Sensitometry of the SO-180 color infrared film used in the Apollo 9 mission with EA-4 processing compared to normal type 8443 CIR film with recommended E-3 processing. It is to be noted that the magenta layer of the SO-180 has a lower gamma than normal (less slope to curve) and thus becomes less sensitive than the infrared sensitive cyan layer at a density of 0.8 (point A). With the two layer sensitivities close to equal at densities below 1.0, there was little shift to a cyan color balance due to air luminance for low density vegetation targets. Most crops, therefore, recorded with a good red record. Dark vegetation targets, such as conifer forest on adjacent mountains, with densities close to 2.0 recorded as blue. Sensitivity of the yellow layer could also have been brought to point A with a CC30M compensation filter.

The SO-180 curves based upon sensitometric testing by NASA, Manned Spacecraft Center.

Section III

Analysis of Crop Color Variations Recorded on CIR Imagery

Analysis of Crop Color Variations Recorded on CIR Imagery

Many crop color responses recorded on CIR film follow predictable changes (i.e., cereal grain crops turn yellow when they mature.) which are most useful in identifying crops, especially when utilizing time-lapse imagery. Unfortunately, predictable crop color changes do not always follow a uniform crop-wide pattern. Because of time variations in farm management practices the same crop has been detected to record a different color response within the same field (Plate 3) and between different fields (Plate 4) while different crops have been noted with the same color response (Plate 5). Changes occuring within the vegetation and the surrounding environment cause the variations in color response, but the recording of the response on CIR imagery is further complicated by the variation in the integration of color responses caused by changes in the ground resolution and/or scale of the image. A factorial analysis of the crop response variations may assist in improving the ability to identify agricultural crops.

A. Changes in Color Response Related to Season

The predictable variations in crop color response related to the growth cycle have been found to occur in:

(1) differences in the crop maturity,

(2) the ratio of soil exposure to vegetative color,

(3) the influence of farming practices (irrigation, cultivation, etc.) on the color response of the soil and vegetation, and

(4) the effect of crop shading on the amount of background infrared illumination.

1. Effects of Differences in Crop Maturity on the Color Response

One of the most important factors in agricultural crop identification is the change of the color response with change in time. The transition of cereal grain crops from the true vegetative color of blue-green to the ripe golden yellow of barley or the bronze color of mature wheat yields false color differences on CIR photography useful in detecting cereal grains at most resolutions. Detection of the temporal change of crop colors requires sequential exposures of the same target throughout the various phenologic stages of a crop's growth. The CIR image color for ripening grain, for example, changes from the deep red of the vegetative stage to the lighter pink of the ripening grain and finally to a yellow, light tan color or yellowish green, depending on auxiliary filtration and processing (Plate 2). Dieter Steiner (1969) found that the ideal time period between successive images for detection of the change in crop color response was three weeks with at least three successive images. Verbal discussions with David Simonett suggested that the timing sequence is tied to the growth cycle in three divisions. In mid-season many crops are at a phenological stage in which their infrared color response appears quite similar and they are difficult to differentiate. During the earlier vegetative stage differences in crops may be detected by differences in planting times. The third division provides the greatest potential in crop differentiation with some crops having ripened to different colors, or showing the effects of different types of harvesting (Plates 7 and 8).

2. Effects of Soil Exposure on the Color Response

The ratio of soil exposure to agricultural vegetative cover changes with the maturity of the crop (Plate 9). A crop that completely covers a field will yield a pure false color on the CIR image; if the crop is in a vegetative stage this will be red. The other extreme may be found in newly seeded fields in which no crop color appears and only the soil reflectance, modified by moisture, creates the color response recorded on the CIR image. The resultant image recorded on the CIR film will be an integrated color combining respective proportions of the color response of the exposed soil and the crop cover. However, the amount of color integration is dependent upon the resolution. At maximum resolution (ground photo, Plate 9) the crop color is separated from the soil color and two distinct non-integrated colors are recorded. Low resolution as exemplified by the Apollo 9 image (Plate 1) yields the maximum integration of combined colors.

3. Influences of Farming Practices on Color Response

Farm management practices are also important contributors to color variations. A frequent practice within a given agricultural area is to stagger planting of annual crops which thus presents several stages of growth of the same crop on the same image. Perennial crops (i.e., alfalfa) may have several cuttings throughout the growing season (Plate 3) and in one instance an image was found with alfalfa fields in six different tones of red from light pink to deep red (Plate 4). The application of fertilizer has a marked effect on the image of the crop by changing the vigor of growth which can be detected on CIR images by deepening the shade of red.

Either irrigation or cultivation will change the amount of soil moisture exposed to the sensor and the integrated color will vary in both hue and tone with the change in the visible moisture conditions. Spectral reflectance characteristics show that dry soil has a much higher reflectivity than wet soil at all wavelengths. The greatest difference occurs in the near-infrared (900-1000 nm) (Condit, 1969). Dry soil, lighter in color, will tend to decrease the overall density of the integrated crop color while wet soil with lower reflectivity will increase the density of the color yielding a darker tone with a shift toward a cyan balance. Examples of the moisture difference phenomena was noted throughout the Apollo 9 photo. The seeded fields were easily detected because of the dark bluish (cyan) color of the very wet soil. Certain cultivated growing crops such as onions showed a combination of modulation of the dark bluish soil background and the vivid red of the vegetation with the result being a magenta color. Differences in bare fields were noted wherein fallow fields were recorded on the CIR film as a neutral color (with EA-4 processing) and the plowed fields yielded a very distinctive turquoise blue.

4. Effect of Crop Shading on Amount of Background Infrared Illuminance

Current investigation related to the IR reflectance characteristics of vegetation (Pease) suggests that vegetation is significantly transparent to near infrared radiation. Thus, vegetation with a shadow substrata will appear darker than the same vegetation with a light or illuminated background. The phenomenon is most marked when the background is illuminated directly by the sun and simply shows through the crop tissue. This effect is dependent on the stage of growth and condition of the vegetation and will

decrease with multiple layering of crop leaves. Soil within an individual field that has been modified by irrigation water will present an even more complicated reflectance pattern. The exposed soil will dry sooner than the soil which is shaded by the vegetation. The variation in the wetness of the soil in the same field may cause a difference in the uniformity of color and certainly can cause a difference in the colors of two fields of the same crop at the same stage of maturity. An adjustment in the scale or resolution will not necessarily reduce the effect of the light contribution of the soil, but the phenomenon may further explain the differences frequently noted in the color records of two identical crops.

B. Variations of Crop Color on CIR Imagery with Changes in Resolution

The change in the color record is quite apparent as the scale and resolution is increased from that of the Apollo 9 image (1:3,000,000 scale; 80 meters resolution) to the large scale and high resolution of the low altitude NASA Mission 73 flight (1:4,000 scale; 10 cm resolution). The high resolution has a most deleterious effect on the readability of crop colors which, as noted in section III-A-2 above is apparently caused by the plant color being visually separated from the associated ground color. The separation effect in high resolution CIR imagery suggests that the color record of an agricultural crop on medium and low resolution CIR imagery must, therefore, be an integrated color reading which is obtained from the combined reflectance of both target vegetation and visible soil background. The plant images on high resolution photography are usually represented by small dots (Plates 5 and 6) which make it difficult to

obtain an average densitometric reading of the entire field. Average values from high resolution imagery may require several readings to be taken for different image elements of each individual field, a process that is not compatible with automatic processing.

Adulteration of the pure vegetation color occurs at least as soon as image resolution is reduced to the CIR film resolution (40 lines/mm) which no longer permits separation of the reflectances of soil and vegetation (Plates 6 and 7). Color blending will continue to increase as the resolution is decreased. At some upper limit the agricultural crops in adjacent fields will also present a cross-modulation between fields and the blended margins will include colors from both. The Apollo 9 image (Plate 1) displays examples of this latter effect. Adjacent fields of the same crop type simply continue the color of each other, but adjacent fields with different crops create a compounded adulteration of the color records of both cells.

Experience during this study has shown that the highest resolution for good color integration on CIR imagery is 40 cm which was noted on Mission 73 at a scale of 1:16,000 (Plate 2).

Section IV

Design of Agricultural Land Use Interpretation and Analysis Systems[2]

The variations in crop color responses originating in the micro--environment of the individual field suggests that any system designed to process agricultural CIR imagery will need to examine each individual field unit or cell. Likewise, the uniqueness of the macro-environment of a region, as noted in the Imperial Valley, suggests that each agricultural region will also have to be examined individually. The environmental differences between regions, both physical and cultural, are so complex that neither a manual nor an automatic universal worldwide systems designed at this time to consider each variable would be practical. The alternative presented here is to use the results of the Imperial Valley study as design criteria for a basic interpretation and analysis system which then, perhaps, can be modified to fit each agricultural area. The basic modification for applying the system to other areas would be the preparation of an appropriate table of crop signatures, develop surrogates of local conditions, and preparation of a local area base map showing individual field patterns. A further expansion of the system would be the design of a world-wide agricultural land use code which could be used in its entirety or only in those parts applicable to the area under study.

The design criteria that follows is intended for a system that would either manually or automatically examine each field or cell, record the

---

[2] The term system is being used rather than methods because it is more indicative of automatic or computer processing techniques and it indicates a repeatable systematic process for each step performed during the interpretation and analysis sequence.

field location index, measure and record the field color response, and then refer to crop signature tables and the field historical data to determine the probable agricultural land use type. Upon complete examination of the entire region various summary reports could be prepared. This type of system requires the preparation of certain tables before any examination of the imagery can begin. The table of crop signatures is one of the first steps before any attempt can be made to perform agricultural land use interpretation.

A. Crop Signature Tables

It has been stated by Bomberger (1960) that agricultural land use interpretation can be made on the basis of tone, texture, pattern, shape, size, and topographic site. Experimentation with satellite color photography has shown that many of these signature factors are lost with the decrease in resolution; however, the color has remained. While, as Strandberg (1968) suggests, color will enhance the resolution capability of the imagery, it is still not sufficient on Apollo 9 imagery to provide much more than gross shape and size information. CIR imagery enhances the separation of cultivated vegetation, but it creates the additional problem of crop color variation discussed in section III. The interpretation of the vegetative color with image elements other than the crops needs additional signature data to help identify individual crop types. These data can be provided by incorporating additional environmental signature facts, both physical and cultural, in the signature table. The complete table should include a list of farming patterns peculiar to each crop type. The design criteria for each of these three signature elements is as follows:

1. Color Signatures

Lack of quality control and sufficient color variation data requires that, at present, color signature tables must be prepared from each set of images. Preparation of a uniform table of color signatures for agricultural crops is impossible at present because of: (1) the previously mentioned lack of adequate quality control in the CIR film manufacture, image exposure, and development processes; and (2) the lack of adequate specific information on the variation in color throughout the growth cycle of each crop. To prepare a table from existing imagery, the ground survey work must be accomplished at the time of the flight to obtain positive identification of representative crops and a sampling for each crop type in various stages of growth.

Despite factors producing color variations, there is still a high percentage of crop types which present a uniform color on a single image - annual crops such as cereal grains, sugar beets, cotton, melons and tomatoes (Plate 2). The uniformity of color within crop type on a single image offers some hope of success in the use of automatic electronic image analyzing devices which are being developed to interpret an entire image without the necessity for examining individual fields. Lack of uniformity in some crops (i.e., alfalfa), however, suggests that it will continue to be necessary to examine certain fields individually using auxiliary signature data before final identification can be made.

An essential requirement in maintaining uniformity in color signature readings is a measuring device which will maintain the same color standard throughout all the imagery. A readout device may be an electronic

scanner which feeds the information to other automatic processing equipment or it may be a manual readout color densitometer which separates the three dye layer modulations into numerical density readings. For application to individual field analysis the latter instrument may be a desirable adjunct in that sets of precise numerical values may be obtained for each field. Recording numerical values for each dye-layer density will enable crop color signatures to be expressed as a ratio between two of the three density values.

The color signature tables should be expressed as upper and lower ratio limits to insure inclusion of the same type crop even when there are slight color variations. If these limits are too broad for the number of crops to be evaluated in a single series of images, then the color signature table should be prepared with subdivisions of crop types and note made regarding overlap of characteristics. The subdivision should consider possible stages of growth and upper and lower limits for each of the stages established. Crops which cannot be identified by color signature tables should be referred to other signature factors for further processing.

2. Environmental Factors

Clues other than color signatures may occur on the CIR imagery or may be available as auxiliary data to reduce the number of identification possibilities. Auxiliary data are those data which occur as physical or cultural factors of the geographic target area.

a. Physical Factors

Among the most useful physical factors is the climate. The agronomist will often divide the cultivated plants into warm weather and cool weather crops. For a given geographical location, the climatic factor

alone enables us to reduce the 1070 cultivated plants listed by Sturtevant (1958) to a more manageable number. Of the usual climatic data for the Imperial Valley, temperature is most useful. Modern technology in irrigation practices has diminished the importance of precipitation there as is exemplified by more than 284 miles of main canals and 1497 miles of laterals. In the Imperial Valley, the temperature extremes have the greatest influence on the crop calendar. (The climatic data for the Imperial Valley is shown in Appendix A-2.) The average 316 frost free days is a poor indication of the growing season in the Imperial Valley. During the winter months, when frost is apt to occur, most of the crops under cultivation, such as lettuce and carrots, have moderate frost tolerances. Hence, the growing season in the Imperial Valley is much closer to 365 days than the frost free calendar would indicate. The climatic factors can usually be summarized and defined in an expanded crop signature table that includes a crop calendar. (Refer to Appendix C-1 for the Imperial Valley Crop Calendar.)

Another physical factor directly connected with climate, but much simpler to define, is the geographical location or limits where various species of vegetation can be cultivated under natural climatic conditions. Date palms for example, have an extreme northern hemisphere limit of approximately 34° latitude. Likewise, bananas have a climatic zone limit that can be described by geographical coordinates. Most of the economic crops can similarly be delimited.

Other indirect physical factors that determine the type of crops which may be planted in the area are local factors such as soil conditions

and importation of water with a high salinity content. The latter problem exists in the Imperial Valley, but is countered by a vast underground tile drainage network that permits ground leaching to remove excess salts. Whenever special local conditions can be stated in definitive form, they may be used to reduce the number of possible crops to be identified in an area.

b. Cultural-Economic Factors

The type of crops produced in a given area or country can also be prejudged to some extent by cultural practices. The diet of the populations of Asia, for example, involves the use of large amounts of rice. In Tongo, one suspects that an abundance of yams are produced. Likewise, in the United States, an investigator would anticipate considerable cropland subsidizing the raising of beef cattle. Diet habits connected with the cultural history of an area supports the idea that tables of crop signatures should be modified for each of the cultural regions of the world to make the job simpler.

Location of the croplands with respect to their markets, cost competition between crops, land costs and export crops are economic factors that should also be considered as crop identification surrogates.

The physical and cultural environmental factors can usually be found summarized in an annual crop calendar for the local area. The selection of crops which appear on the calendar are greatly affected by physical factors, but within the frame of possibilities offered by the physical environment are local cultural factors which dictate crops planted.

3. Farming Patterns

The major divisions of agricultural productions (Field Crops, Vegetable Crops, Fruit and Nut Crops, Livestock and Animal Production, and

Horticultural Specialties) each have distinctive patterns resulting from farming practices. Field crops are generally noted for their extensive farming practices, and the majority of crops which are planted by broadcasting or drilling the seed are identified as field crops. Vegetable crops normally consist of intensive farming practices with mechanized crops planted mostly in rows. The rows are for either irrigation or the necessary crop care of periodic cultivation, fertilizing, spraying, and manual or mechanized harvesting. However, certain field crops are planted in rows also for the same type of care, so the fact a field contains rows does not necessarily identify the type agriculture being practiced. However, the rows of specific crops are often distinctive. For example, spacing of watermelon rows is generally 9 feet (2.74 meters) in the Imperial Valley while Field crops of cotton and sugar beets and many of the vegetable crops are only 42 inches (107 cm.) apart. Within the vegetable crops, the number of rows within a hummock or hill is found to be different. Carrots, in contrast to watermelons, may be planted in closely spaced multiple rows within double rows one foot (30 cm.) apart on either side of the hummock.

The size of a field or the uninterrupted cover area within a field is very indicative of the type of agricultural crop as well as the harvesting method employed. Most large field crops can be harvested mechanically and the only limit on the field size is land ownership and practicality. Grain fields may have an unbroken cover for miles in a dry farming area. In irrigated areas the length of a grain field is limited by ownership and the fall of the land to contain or spread irrigation waters or run sprinkler

systems. Vegetable crops are quite different in size requirements. Manual harvesting has limited the length of an unbroken row of vegetables to the distance a human can carry the product. Hand picked canteloupe are usually limited to rows of a distance that a picker can carry a full bag before unloading. Mechanized harvesting may impose size limits and also spacing limits. Conveyor belts on a semi-automatic watermelon harvester will reach across only 9 rows. Therefore, the tenth row in a watermelon field is bare to facilitate the movement of a harvester. Because vegetables must be irrigated, the size of the field is limited to the fall of the land for flood irrigation or the practical length of pipe for sprinkler irrigation.

Farming practices are thus a very distinctive aid in interpreting agricultural land use. While they all may not be present in a particular image because of the resolution, those which are present can be used effectively to categorize the land use or crop types.

B. Worldwide Agricultural Land Use Code

The development of the coding system for any land use mapping is the keystone to the entire interpretation and analysis process. The success of the system will stand or fall on the adequacy of the classification divisions to accept and distinguish as many land use types as possible and its ability to present the data to the user in a form that will enable solutions to as many problems or questions about the area as possible. These questions may be those of the regional geographer who desires to determine the economic culture of the area, the market analyst who wants to know how many refrigerated rail cars will be needed, or even the hydrologic engineer who must plan for the delivery of water for the season.

1. Requirements

The four prime requirements for an Agricultural Land Use coding classification system are as follows:

(a) be able to accept and distinguish as many agricultural land use types as possible throughout the world without overlapping, duplicate or ambiguous categories;

(b) be acceptable in classification divisions and titles to a wide spectrum of users;

(c) be compatible with or adaptable to computer or machine processing techniques; and

(d) permit the interpreter to categorize all land use types with the highest possible accuracy consistent with the resolution of the imagery being examined.

2. A User Oriented Land Use Code

Requirement (d) above, suggests a hierarchical classification system wherein the categories become more generalized as the resolution becomes less distinct. Acceptability of titles to the major users, laymen, suggests commonly accepted terms of the farmer be used rather than the biological titles of the scientist. Computer or machine processing suggests the use of pure decimal numerals rather than a mixture of letters and numerals. A system that has been developed, is gaining wide acceptance, and meets three of the above four requirements has the unassuming title of Standard Land Use Code. The code was prepared in 1965 by the Urban Renewal Agency in conjunction with the Bureau of Public Roads. The Standard Code, as originally prepared, falls short of providing for complete worldwide agricultural classes and lacks

sufficient number of divisions for the majority of users. Understandably, the code was prepared for use within the United States - primarily for urban and regional planners. However, the preface to the publication states that users should expand or adapt the code to individual needs. The San Diego County planning commission has made such an adaptation to fit the categories found in their county (San Diego County 1968)).

Probably no single code can be produced for all users. On the other hand, experience in the Imperial Valley suggests a single code can be produced to provide for the planner viewing the scene from the ground as well as the interpreter utilizing aircraft or even satellite imagery taken from 10 miles. The Code will require one more digit than is used in the standard code and possibly an additional suffix for the specialist who desires to know if the crop is irrigated or dry, or a cash or a feed crop, or state of crop maturity.

The standard land use code does utilize agronomic and horticultural names and is a classification commonly used by farmers and laymen. The specific crop type of barley (fifth digit level), for example, fits into the hierarchical classification in the secondary agricultural land use of cereal and grain crops (fourth level), in the primary agricultural land use category of Field Crop (third level), in the rural land use of Agriculture (second level), in the general land use of Resources and Production (first level). An alternative agricultural land use classification system might be to categorize crops by the distinguishing features or patterns of the objects being detected. Although such a system is very convenient for the interpreter, he is only doing part of the task. Such signature classification

might place the row crops of sugar beets, cotton, most vegetables, and perhaps some fruit and nut crops all in one category. A user of such a list would have a difficult time making any judgements about a region if he were told it contained 100,000 acres of row crops. The interpreter must use the pattern signatures of a crop, such as the fact it is planted in rows, to assist in establishing the utility of the crop classification or the activity undertaken. If the land is supporting 30,000 acres of forage crops, 20,000 acres of grain crops, 50,000 acres of fiber crops, and contains 100 cattle feed lots, he can make a considerable judgment about the agricultural base and economy of the area.

Because many users need to know how many acres of a specific type of crop are under cultivation in order to plan for harvesting, storage, and transportation, or to make farm loans with reasonable safety, or for many other planning purposes, the code needs to specify the individual crop. The standard code has, therefore, been expanded to five digits from the original four. Duplication of numeral codes to indicate cash crops or grain crops of the same type, or irrigated vs. dry farming have been eliminated. These items can be identified by a letter suffix by those users who need further detail.

3. Hierarchical Five-Digit Level Code

The Urban Renewal Agency (URA) standard land use code employees a four digit level code. The first digit on the left is the most generalized category and the fourth digit (on the right) is the most detailed activity. In the five digit adaptation the fifth digit lists the specific crop type. Appendix C-2 contains the complete Agricultural five digit level land use

code developed for this study. The digit level categories are summarized as follows:

Digit Level	Category	Code and Description Example
First	General Land use	8 Resource Production and Extraction
Second	Rural Land use	81 Agricultural
Third	Primary Agricultural Land use	811 Field and Seed Crops
Fourth	Secondary Agricultural Land use	8111 Cereal and Grain Crops
Fifth	Specific Crop Type	81111 Barley

Establishment of the five digit-level code as an hierarchical system permits the interpreter to attempt specific crop identification without jeopardizing the accuracy of the classification system at some higher level; i.e., the error of classifying wheat (81118) as barley (81111) does not affect the accuracy of classifying cereal grains (8111). Reciprocally, the hierarchical system facilitates a more accurate specific type classification by providing for an initial division into broad categories of land use types. Field crops (811) are generally comprised of large acreage or extensive farms, while vegetable crops (812) are the smaller or more intensive farms.

The resolution of the imagery being examined will influence the digit--level accuracy. CIR imagery of very low resolution will permit distinction of agricultural land (81) noted by the regular red toned patterns of the cultivated lands. Increase of resolution to that of Apollo 9 (80 meters)

reveals field patterns and sizes that will generally indicate intensive vs extensive farming practices and in conjunction with auxilary environmental data may permit third digit-level (811) distinction of crops. Resolution requirements for fourth and fifth-digit levels were not determined during this study. However, it was found that specific crop types (fifth digit--level) were identified with nearly 100% accuracy from imagery with 40 cm resoltuion,[3] but it is quite possible that a lower resolution will still permit equal accuracy at this fifth digit-level.

C. Design and Preparation of Local Base Maps

Current efforts in remote sensing land use mapping indicates that the procedure (manual or automatic) will be facilitated by the use of a base map which contains the field patterns of the agricultural crop lands under investigation.

1. Selection and Use of Control Map

Convenience in availability and the detail of preparation has made topographic maps the most commonly used base map in rural land use mapping. However, the very fact of the great amount of detail often makes these maps difficult to use when the final land use map is prepared. Also the normal topographic maps do not contain all of the field divisions that are normally encountered. An alternative method is to prepare a new base map of the area from the imagery being utilized and use the local topographic map as a control for accurate planemetric representation.

A convenient scale for agricultural land use mapping in the U.S. has been found to be 1:62,500. Fortunately most of the United States

[3] Mission 73, Western Aerial Surveys, June 1968.

agricultural areas have been mapped by USGS at this scale. Ideally the base map for aerial or satellite imagery should be orthophoto maps, but satisfactory maps can be prepared using modern automatic cartographic equipment or the somewhat less expensive simultaneous film-map viewers. Lacking the above type equipment, a method was devised for this study to reduce the filmed image to map scale by means of a photo enlarger/-reducer. Strip sections from the control map coincident with the flight line of the imgery were traced on acetate overlays. The filmed image was then projected onto the tracing for completion of the field patterns with correction and rectification for film and platform distortion being made as necessary. The final base map was then prepared by transferring these strip overlays onto a full size overlay of the control map.

2. Adaptation of Coordinate Systems

Detailed agricultural land use, unlike some other types of land use, is often a dynamic process, changing daily. To observe the quantity of changes occurring over an extended period of time will require the use of automatic data processing. To facilitate such processing it will be necessary to index the fields to provide for retrieval of all previous data for any given field. Indexing must provide for both worldwide location and local identification.

a. Geographic Coordinate System Modification

The early scientists who created the geographic coordinate system did not have modern day computers in mind when the system was established. Consequently, any computations of distances or the recording of locations requires a considerable number of calculations and digits. Much

of the calculations and numbering can be simplified by the use of decimal fractions of each degree of latitude or longitude. To assist in computer processing, both the local area coordinates and individual field coordinates, when used, have been established in this study by decimal fractions of each degree. It would also be desirable to perform area computations utilizing the geographic coordinates. The odd shaped fields that are encountered throughout the world make such computations difficult and many problems need to be solved before complete machine computations can be accomplished.

The field shape problem is not so great in the Imperial Valley since most of the fields are rectangular. By using the decimal geographic coordinates at each corner of a field the distance between points and the acreage can be calculated by a computer with only one additional factor included in the machine instructions. The factor would be the length of one degree at any given parallel on the earth grid.

The decision to locate the geographic coordinates of a field at the corner rather than the center of the field may prove a handicap when less rectangular shaped fields are encountered. For the present, geographic coordinates of the local region, as well as the fields, have been indicated for the Greenwich/Equator (G/E) corner of the region or field. The G/E corner is defined as that corner nearest the 0° or Greenwich longitude and 0° or equatorial latitude. In the northern hemisphere - west of Greenwich - the coordinate is in the southeast corner of the field.

b. Local Grid System

Often it may be desirable to indicate geographical coordinates for just the local region and use a local index system for individual field location. If land tenure does not vary to any large degree and once the acreage for a given field has been determined, the index will remain relatively constant. A basic land unit of 160 acres (65 hectares) exists throughout the Imperial Valley. Historically, the land unit dates to the original homesteading of the Valley in 1901 when the Desert Lands Act permitted the settling of 160 acres. Unfortunately, the survey in existence at the time was not accurate and the correct term for a basic land unit in the southern half of the valley is 160 acres more or less. Later purchases of the railroad and school lands and the land in the northern part of the valley were made after a corrected survey and the acreage had been more accurately determined. The variations between the southern half of the valley can be seen on maps in the appendices. The 160 acres representing a quarter of the one square mile (2.6 sq km) sections of the Township and Range cadastral survey provide a uniform one-half mile (0.8 km) to the side square pattern throughout the valley. Consequently, a cartesean coordinate index system consisting of one-half mile divisions provide a naturally derived grid. It was necessary to use quarter-mile divisions in the west central area around Brawley which was displaced one-quarter mile in a North-South direction because of survey adjustments and inaccuracies. Where the basic land unit of 160 acres has been divided into smaller fields a letter suffix has been added to the index number. The suffixes start with the letter 'A' in the upper right hand corner and proceed counter-clockwise around the 160 acre unit.

Similar local grid systems in all parts of the world should be facilitated by use of basic land unit theory. In addition to historical background in land tenure, political factors are also a consideration. In the western United States, the 1902 Land Reclamation Act limiting the distribution of water from federal reclamation projects to owners of 160 acres has a pronounced effect on the land unit. Government control and relocation of agricultural units in areas such as the Mexicali Valley of Baja California have an effect on the land unit. Other factors no doubt influence the establishment of a basic land unit. Many of these conditions become apparent once the field areas are mapped and a study is made to determine the local pattern.

A step by step outline of the procedures to be followed in the interpretation, mapping and analysis of CIR imagery is contained in Appendix B.

Section V

Correlation of Photographic Interpretation with Actual Ground Data

Receipt of the Apollo 9 CIR photography provided a timely input for testing the interpretive and analysis system outlined in the preceding section and appendix B. The sequence of imagery inputs from aircraft overflights of the Southern California test site enabled the NASA mission 73 imagery to be used for the development of interpretation procedural methods, preparation of the base map, and familiarization training. This preparation permitted the Apollo 9 imagery to be used to provide testing of the processing system as well as testing of small scale CIR imagery.

A. Assumptions and Methods of Correlation

The availability of Crop Calendars for many agricultural areas suggests that considerable knowledge is available about agricultural areas of the world. Crop Calendars can be used to reduce the crops which must be considered in a given area at a given time. The accuracy of determining agricultural land use can be considerably improved if the area is thought of as a region of known culture rather than an unknown hostile military target. Development of surrogates of local peculiarities will greatly increase the accuracy of results.

1. A priori Knowledge of the Test Site Area

In developing the processing system which led to the interpretation of the Apollo 9 photography many ground surveys of the Imperial Valley were conducted and several discussions were held with local agricultural advisors. The result was an accumulation of information pertaining

to the farming practices in the Imperial Valley which included the knowledge that certain crops are localized in production, (i.e., asparagus crops are centered around the local cooperative association in the central area of the southwest corner of the valley and carrots are localized around Holtville, "The Carrot Capital of America", etc.). Additional essential preinformation for the Apollo 9 photo interpretation was made available from Mission 73 analysis with nearly 75 percent of the previous crops being identified. Thus, the plausibility of crop sequences was ascertained for many of the fields during the interpretation of the Apollo 9 photo. In other areas, localized a priori knowledge may not be available to the interpreter, but much of information can be developed from repeated flights. Hence, the test of the processing system on the Apollo 9 photo provided simulated conditions that could well exist after several missions had been flown over the area.

2. Ground Surveys for Correlation Studies

To provide accurate data for the development of crop signatures for the Apollo 9 photo, a ground survey of Imperial Valley was conducted coincident with the first day of Apollo 9 overflights. On this initial survey, 586 fields were examined and identified representing 7.5 percent of the 7801 fields subsequently identified.

After approximately one-half of the satellite photos had been interpreted, a second ground survey was conducted on May 10 with the data already obtained reconstructed to the conditions existing on March 12, the date of the Apollo 9 photo. The second survey examined 447 fields (5.7 percent of total). A third survey was made on May 21 for purposes not

connected with the Apollo 9 photo analysis, but data was obtained that could be reconstructed back to March 12 thus providing 463 more fields (6 percent of the total) for identification correlation analysis. The three surveys provided a total of 1507 fields (19 percent of total) visually identified by ground inspection. The field sample data has been correctly indicated on the final Agricultural Land Use Map of the Imperial Valley. (Appendix C-3).[4]

3. Representative Selection of Survey Data

Like most statistical correlations, the question arose whether the 13 percent sample represented by the latter two surveys was representative of the field population? The selection of a truly random sample in the Imperial Valley was biased by the usual human choice of crops planted in a given location as well as physical limitations as to where a particular type crop may be grown. No attempt was made to select random samples by the usual statistical methods. The first training survey was not used in the correlation analysis, therefore the only effect it had on the correlation was to eliminate some of the possible samples from duplicative efforts. The two ground surveys that were used for correlation analysis were not completely random in selection, nor were they completely planned. Both were taken in the more southern portion of the valley in order to obtain a representative cross section of crops. The large acreage fields (160 acres) north of the east section were particularly avoided because they are limited to the field crops of alfalfa, barley, sugar beets, and cotton. Survey time was better spent in areas of smaller acreage fields

[4]Readers who desire this ground information may find the route of each survey track listed in Appendix C-4.

and more diverse crop types. An indication the latter two surveys were a representative sample was that correlation analysis performed on them separately resulted in almost identical findings. A later survey, not included in this study, was given a test correlation with the interpreted data and the results were again identical. While the above did not yield statistically derived confidence limits or significance, the evidence provides a basis for believing the conclusions drawn from the correlation are valid.

B. Correlation of Apollo 9 Crop Identification with Ground Survey Data

The arid conditions of the Imperial Valley make it a simple matter to distinguish the agricultural land from the non-agricultural land. To produce vegetation and to continue its growth requires the importation and application of water. Consequently, a glance at the Apollo 9 photograph of the Imperial Valley illustrates the growing croplands in their red false color image. Even cropland that has no visible vegetation can be detected by the surrogates of surface moisture through irrigation of newly seeded fields, or the exposure of soil moisture through plowing. The ease with which agricultural land can be detected within the Imperial Valley on CIR imagery makes the detection accuracy at the second-digit level of the Agricultural land use code nearly 100 percent. The correlation analysis of this study is then concerned with the accuracy of the third digit level (primary agricultural class) and the fifth digit level (specific crop type).[5]

[5] An Imperial Valley and Coachella Valley agricultural land use map produced by Richard Francaviglia from Gemini V normal color imagery was limited to three categories, i.e., permanent crops, fallow land, and field crops. For further information see Bowden, 1967 and Nunelly, 1968.

TABLE II

CORRELATION OF LAND-USE IDENTIFICATION WITH GROUND SURVEY CHECK: APOLLO 9 CIR IMPERIAL VALLEY IMAGE (MAR 11, 1969)

AGRICULTURAL CLASSIFICATION		IDENTIFICATION ACCURACY WITHIN CLASSIFICATION (Digit Level)								
		PRIMARY CLASSIFICATION (Third Digit Level)			SECONDARY CLASSIFICATION (Fourth Digit Level)			SPECIFIC CROP (Fifth Digit Level)		
AGRICULTURE	81	SAMPLE SIZE	ACCUMULATIVE CORRECTLY IDENTIFIED	%	SAMPLE SIZE	ACCUMULATIVE CORRECTLY IDENTIFIED	%	SAMPLE SIZE	NUMBER CORRECTLY IDENTIFIED	%
FIELD CROPS	811	606	537	88.6						
GRAIN CROPS	8111				150	62	41.3			
Barley	81111		(79)			(56)		140	53	37.9
Wheat	81118		(9)			(6)		10	0	0.0
FORAGE CROPS	8113				319	200	62.7			
Short Grass (Rye)	81131		(10)			(7)		11	0	0.0
Alfalfa	81133		(264)			(193)		308	193	62.7
SUGAR CROPS	8114				132	27	20.5			
Sugar Beets	81142		(130)			(27)		132	27	20.5
OIL CROPS	8117				5	0	0.0			
Flax	81172		(4)			(0)		5	0	0.0
FIELD CROP TOTALS					606	289	47.6	606	273	45.0
VEGETABLE CROPS	812	40	23	57.5						
SALAD CROPS	8123				18	13	72.2			
Lettuce	81231							18	13	72.2
ROOT CROPS	8127				10	7	70.0			
Carrots	81272							10	7	70.0
BULB CROPS	8128				12	3	25.0			
Onions	81284							12	3	25.0
VEGETABLE CROP TOTALS					40	23	57.5	40	23	57.5
NON-PRODUCING & TRANSITION LAND	818	266	247	92.9						
FALLOW	8181				32	26	81.3			
PLOWED	8182				130	120	92.3			
LEACHED	8183				1	1	100.0			
ABANDONED	8184				39	37	94.9			
PREPARED & SEEDED	8186				64	63	98.4			
NON-PROD & TRANS LAND TOTALS					266	247	92.9	266	247	92.9
GRAND TOTALS		912	807	88.5	912	559	61.2	912	543	59.5

1. Correlation of Specific Crop Identification (Fifth Digit Level)

Table II summarizes the results of the correlation between the Apollo 9 interpreted data with the ground survey data from 912 fields (13 percent of the field population total). The overall accuracy of 59.5 percent for the Specific Crop identification is not only a poor result, but it also is a poor indicator of the actual results. The excellent results obtained in the Non-producting and Transition crop lands is masked by the poor results obtained from the three major crops (barley, alfalfa, and sugar beets) in production on the date of the Apollo 9 flight. The vegetable crops surveyed are too few to be of statistical significance. A primary question is, "Why is the identification accuracy of field crops so low (45 percent) and, in particular, why is the sugar beet accuracy only 20.5 percent?"

An analysis of errors on the misidentification of the three main field crops show the following results:

Table III: Analysis of Errors on Field Crop Identification

Crop Type		Identified as (%):			
	Errors	Barley	Alfalfa	Sugar Beets	Plowed Land
Barley	87		58.3	22.6	
Alfalfa	115	40.4		24.5	18.1
Sugar Beets	105	29.5	59.9		

Several reasons may exist for such a large percentage of error with the most likely being that the maturity of the three crops on March 12 is such that they generally present the same small scale CIR color image. The dark red did not necessarily equate to one specific type crop with light reds showing another type crop. No doubt, moisture conditions in the individual fields created color differences among a specific crop type - especially alfalfa. The 18.1 percent of the alfalfa fields, misidentified as plowed land, implies moisture was a major factor in causing identification errors. Another factor was the unusually large number of weeds in the sugar beet fields which simulated alfalfa. The abnormal and untimely winter rains of 1968-69 germinated a large weed crop which in some cases entirely covered the sugar beets. The large error of field crop identification indicates that additional information is required at this time of year to provide specific crop information.

2. Correlation of Primary Agricultural Categorization

The majority of errors within the field crop class were within the class itself so that the overall differentiation of Primary agricultural classes was a reasonable 88.5 percent. There were at least three contributing factors: (1) The separation of the Non-producing and Transition Crop Land was obvious by the non-red (blue or neutral color) of the field area. (2) The vegetable crops were smaller size acreages (predominantly 40 acres, but never in excess of 80 acres) and familiarization with the area provided clues as to the location of the vegetable crops. (3) The two main vegetable crops (lettuce and onions) each had an easily identifiable color that enabled even the small intensive type acreages to be classified.

3. Agricultural Land Use Not Identifiable or Not Detectable

Several agricultural land use categories within the Imperial Valley were not recognizable on the Apollo 9 imagery. In general, small areas (less than 20 acres (8 hectares)) could not be established as distinctive from other croplands. However, three types of land use concerned (feed lots, tree crops, and asparagus) are permanent type crops or land use and once established the identification will remain constant for several years. These three land uses have been located on the land-use map (Appendix C-3) by ground survey and have not been included in the correlation statistics presented here. Inspection of images of several feed lots on the Apollo 9 photo reveals a color that matches plowed or seeded fields. Tree crop areas in the Imperial Valley are too small and too few to establish a color signature for the Apollo 9 image.[6] Asparagus fields are found in a variety of stages in March with too few fields of similar maturity to establish a consistent color signature.

C. Correlation of Apollo 9 Acreage Summary with Reported Crop Acreage

Three times a year the Imperial Irrigation District prepares a Report of Crops Growing. Fortunately, one of the periodic reporting dates is March 15, which permitted an exact acreage correlation to be made. The Irrigation District Report is prepared from visual reports by 30 zanjeros or "ditch riders" who control water deliveries to each field. There is a possibility of errors in the reporting system, but over the years it has become accepted by the valley farmers as "the reliable report".

[6] However, the nearby Coachella Valley has an abundance of date palms, citrus groves, and vineyards which are detectable on CIR from aircraft altitudes and generally identifiable on the Apollo 9 imagery.

1. Correlation of Specific Crop Type Acreage (Fifth Digit Level)

Specific crop type acreages are compared in Table IV. The summary for grain crops show that it was impossible to differentiate the wheat or oats from barley. In fact, the only wheat or oats identified on the Apollo 9 photograph were those fields visually checked by ground survey. The forage crop summary reveals a definite prejudice in the interpretation evidenced by 18 percent more alfalfa acreage being identified than actually existed at the time. Alfalfa represents 34 percent of the total crop acreage in the valley, hence an interpreter would be inclined to lean toward alfalfa identification when in doubt. Another factor in the excess of alfalfa acreage is the suspected effect on the color of sugar beets by weed cover in the fields. The table reveals alfalfa overestimated by nearly the same acreage that sugar beets are underestimated.

Vegetable crop accuracy attained on asparagus and other crops is not shown since most were identified from ground survey data, or from previous image interpretation. The only three vegetable crops with sufficient acreage to make a valid comparison are lettuce, carrots and onions. The high percentage of accuracy in identifying lettuce is a confirmation of the distinctive red record that lettuce presents in March in the Imperial Valley. On the other hand, carrots are near the end of the harvest season and considerable error can occur between the date of ground observation and the date of the Irrigation Districts report. Lack of sufficient initial ground survey data to establish a firm color record for carrots on the Apollo 9 image may also be a cause of the differences in the carrot acreage. Onion crops have a distinctive color on the Apollo 9 image, but many of the onion fields are

TABLE IV

SUMMARY OF CORRELATION BETWEEN REPORTED AND DETECTED AGRICULTURAL CROP ACREAGE IN THE IMPERIAL VALLEY (March 15, 1969)

Summary:	Acreage		Difference		
Agricultural Land Class	Reported	Detected	Over*	Short*	Percent Accuracy*
811 Field Crops	315,858	292,440		23,418	93
812 Vegetable Crops	21,162	20,574		588	97
813 Fruit & Nut Crops	2,309	668			
8186 Prepared & Seeded	51,160	50,980		180	97
816 Pasture Land	682	120			
Unidentified Ag. Land		6,980			
Total Land With Growing Crops	391,171	371,752		19,419	94.8
818 Non-Productive Ag. Land		93,180			
Total Available Ag. Land	474,437	464,932		9,505	98.0
Individual Crops:					
811 Field Crops					
111 Barley	72,829	68,350		4,479	94
115 Oats	2,423	140			
118 Wheat	9,932	1,100			
Total Grain Crops	85,184	69,590			
131 Short Grass (Rye, Bermuda)	14,714	4,490		10,224	31
133 Alfalfa	134,692	163,420	28,728		82
Total Forage Crops	148,714	167,910			
141 Sugar Cane	2				
142 Sugar Beets	79,679	54,350		25,329	68
Total Sugar Crops	79,681	54,350			
172 Flax	2,279	590		1,689	26
TOTAL FIELD CROPS	315,828	292,440			
812 Vegetable Crops					
211 Asparagus	2,832	3,100			
221 Beans, Green (Fava)	85	85			
223 Peas, Green	74				
224 Okra	51				
231 Lettuce	7,601	7,840	239		97
232 Celery	4	4			
234 Parsley	1				
236 Chicory	3	3			
237 Mustard	32				
Total Salad Crops	7,641	7,847			

*Only valid comparisons of individual crops have been made. No comparison has been attempted for those crops in which the majority of the detected acreage reported is the result of ground survey information (i.e., Wheat and Oats).

Individual Crops (cont.):	Acreage Reported	Acreage Detected	Difference Over*	Difference Short*	Percent Accuracy*
241 Broccoli	289	72			
243 Cabbage	224	240			
244 Cauliflower	40				
Total Cole Crops	553	312			
272 Carrots	4,127	5,580	1,453		74
274 Potatoes (Chinese)	3				
Total Root Crops	4,130	5,580			
282 Garlic	391				
284 Onions	5,405	3,650		1,755	68
Total Bulb Crops	5,796	3,650			
TOTAL VEGETABLE CROPS	21,162	20,574		588	97
813 Fruit & Nut Crops					
314 Grapes	2				
322 Apricots	19				
330 Citrus, Undifferentiated	324	600			
331 Grapefruit	507				
333 Lemon	276				
335 Orange	611				
337 Tangerine	400				
Total Citrus Crops	2,118	600			
342 Dates	93	60			
363 Pecans	77	8			
TOTAL FRUIT & NUT CROPS	2,309	668			
860 Prepared and Seeded Land					
113 Corn	80				
114 Sorghum, Grain	9,510				
132 Tall Grass (Sudan)	1,145				
151 Cotton	20,888				
Total Seeded Field Crops	31,623				
250 Melons, Undifferentiated	1,053				
251 Cantaloupes	11,861				
252 Cucumbers	50				
253 Crenshaw melons	22				
255 Squash	336				
256 Watermelons	3,709				
Total Curcubit Crops	17,031				
TOTAL PREPARED & SEEDED LAND	51,160	50,980	180		99.6

*Only valid comparisons of individual crops have been made. No comparison has been attempted for those crops in which the majority of the detected acreage reported is the result of ground survey information (i.e., Wheat and Oats).

Other Agricultural Land	Acreage Reported	Acreage Detected
610 Pasture Land	682	120
Unidentified Ag. Land		6,980
818 Non-Productive Land		
810 Fallow Land		35,110
820 Plowed Land		35,560
830 Land Being Reclaimed: Leached		1,540
840 Abandoned Ag. Land		20,620
850 Harvested Land		350
TOTAL NON-PRODUCTIVE AG. LAND		93,180

small and difficult to detect which is the reason for most of the difference in onion acreage comparison.

Ground inspection permits the field surveyor to see certain type crops that have been planted (i.e., melon plants under caps), but such fields present only a single bluish color tone on the Apollo 9 image. The result of soil reflection modified by irrigation. Therefore, these crops where identified by Irrigation District report have been grouped under the Apollo 9 classification of prepared or seeded. The 99.6 percent accuracy for this class of land use verifies how easy it is on CIR imagery to identify fields that have been seeded and are under irrigation.

The Irrigation District reports non-productive land only once per year so that no comparison can be made for the month of March. However, the detection of this acreage by its light, almost neutral, color enables an overall comparison to be made of land available for farming within the Imperial Valley.

2. Correlation of Primary Agricultural Class Acreage (Third Digit Level)

The summary of acreage by agricultural class confirms some of the findings presented in the specific crop identification correlation discussed above. Although specific crop type cannot always be identified, the class (i.e., field crop, vegetable crop, seeded land) maintains consistency in detection as indicated by over 90 percent accuracy in establishing acreage for the three major classes of agricultural land use, field, vegetable, transition and non-productive.

3. Correlation of Total Cultivated and Available Cropland Acreage

A slight difference of 5.2 percent between CIR detected acreage under cultivation and reported acreage is a tolerable error of the interpretation system. The method used in the detected acreage summary is to list the total gross acreage of a crop as estimated from the base map and automatically deduct 10 percent from the gross acreage for roads, canals, drains, service areas, and farm areas. Ten percent has been established within the Imperial Valley as the average acreage that is lost from the production of each field for these various purposes. Also errors may occur because the fields in the southern half of the valley are not always exact divisors of 160 acres (the basic land unit) due to errors in the survey system existing at the time the land was homesteaded.

The total estimate of 464,932 acres (188,158 hectares) of agricultural land within the Imperial Valley is within 2 percent of that reported available during the year 1968 (474,437 acres (189,775 hectares)). The latter estimate is well within accuracy tolerance of the processing system.

D. Consistency of Error Between Correlations

The major sources of error in the two correlations above were found in differentiating between the same crop types (alfalfa, sugar beets, and barley) and in the same proportions in both correlations. A comparison of errors for these three crops in the two correlations is shown below:

Table V. Comparison of Errors of Selected Field Crops

	Identification Correlation		Acreage Correlation	
	Percent Over	Percent Short	Acreage Over	Acreage Short
111 Barley		18.3		4,479
133 Alfalfa	53.7		28,728	
142 Sugar beets		35.4		25,329

The discrepancies in the identification correlation of Table V represents the difference remaining after adjustment for cross-identification, (i.e., 58.3 percent of the barley fields surveyed were identified as alfalfa while only 40 percent of the alfalfa fields were cross identified as barley, leaving a total shortage of 18.3 percent in barley field identification.)

The inability to differentiate accurately between these major crops reaffirms the problem of color variations for specific crops. Improvement in identification accuracy from satellite CIR imagery will occur with better standardization of CIR color records. However, improvement may be obtained from better resolution or by time-lapse photography.

Section VI

Conclusion

The production of a complete agricultural land use map from small scale satellite imagery of a region such as the Imperial Valley is most encouraging (Appendix C-3). Two factors permitted the attainment of this goal: (1) CIR imagery that provided distinctive color records of the separate crop types, and (2) availability of *a priori* information. Without either the task would have been impossible.

Lack of accuracy in differentiating individual crop types was due to: (1) lack of sufficient research into the subtle variations of individual crop colors recorded on CIR imagery at Apollo 9 resolution, and (2) lack of sequential or time-lapse imagery designed to take advantage of seasonal crop color variations. Availability of time oriented imagery would improve not only the ability to distinguish between crop color signatures, but would also assist identification by providing a permanent history of the individual field units.

The laborious task of completing the test mapping in this study has shown that timely agricultural land use mapping from volumes of imagery that may soon be obtained from satellites will require automatic or semi-automatic processing utilizing an appropriate land classification system. Repeated surveys of a region will be facilitated by the maintenance of a historical file of individual field units or cells, especially when utilizing sequential or time-lapsed imagery. Certain criteria for a semi-automatic system have been outlined here with the intent that a computer can be employed in the system to provide data storage and retrieval as well as performing the identification task from input data read directly from the imagery.

Because of the dependence of automatic image readout systems, including electronic image analyzers, on the image color variations for performing crop identifications, continued research must be conducted into the crop color variations that are being recorded on CIR and B/W multispectral imagery. Hopefully, results of further investigation will permit electronic analysis equipment to differentiate in spite of inconsistent subtle image color variations for a particular crop. Subsequently, an entire image of a region, like the Imperial Valley, can thus be reliably interpreted by fully automatic methods in a very few minutes.

BIBLIOGRAPHY

Bomberger, E. H., et al., 1960. "Photo Interpretation in Agriculture," Manual of Photographic Interpretation, (American Society of Photogrammetry, Washington, D.C.).

Bowden, L. W., N. J. W. Thrower and C. E. Tiedemann, 1967. "Status Report on Remote Sensing of Southern California and Related Environments," Status Report I USDI Contract 12-08-0001-10674, October, (University of California, Riverside and Los Angeles, California).

Condit, H. R., "Spectral Reflectance of Soil and Sand," 1969, New Horizons in Color Aerial Photography. Seminar Proceedings of the American Society of Photogrammetry and the Society of Photographic Scientist and Engineers, June, (American Society of Photogrammetry, Washington, D.C.), pp. 3-17.

Egan, W. G., 1969. "Practical Calibration and Control Techniques for Type 8443 and Ektachrome Films," Grumman Research Department Memorandum RM-443J, (Grumman Aircraft Engineering Corporation, Bethpage, New York).

Jaques, H. E., 1958. "How to Know the Economic Plants," (Wm. C. Brown Co. Publishers, Dubuque, Iowa) p.2.

Nunelly, N. R. and R. F. Witmer, 1968. "A Strategy for Developing Classifications of Land Use as Interpreted from Remote Sensing Imagery," ASP/ACSM Technical Papers on the 28th Meeting, (American Society of Photogrammetry, Washington, D.C.).

Pease, R. W. and L. W. Bowden, 1969. "Making Color Infrared Film a More Effective High Altitude Remote Sensor," Remote Sensing of the Environment, Vol. 1, No. 1, 1 March 1969 (American Elsevier Publishing Co., Inc., New York, N.Y.).

Steiner, D., 1969. "Using the Time Dimension for Automated Crop Surveys from Space," American Society of Photogrammetry Technical Papers From the 35th Annual Meeting, March 9-14, 1969, (ASP, Washington, D.C.) pp. 286-299.

Strandberg, C. H., 1969. "The Language of Color," Manual of Color Aerial Photography, (American Society of Photogrammetry, Washington, D.C.).

San Diego County Planning Department, 1969. "Standard Land Use Code, San Diego Region, Topical-Descriptive Index," Comprehensive Planning Program, (Planning Department, County of San Diego, California).

Urban Renewal Administration, 1965. Standard Land Use Coding Manual, First Edition, (Supt. of Documents, USGO, Washington, D.C., 20402).

Appendix A

Description of Imperial Valley

1. Geographical

Geographically the Imperial Valley is bounded between latitudes 32.7° North and 33.3° North and longitudes 115.3° West and 115.8° West. An area of 34 statute miles (54 km) east and west and 48 statute miles (77 km) north and south, it encompasses 655,680 acres (262,272 hectares) between the highline irrigation canals which bound the east and west sides of the valley. Within the above acreage there is a total of 474,437 (189,775 hectares) farmable acres with an additional 14,716 acres (5,866 hectares) devoted to farms in homes, feed lots, cotton gins, experimental areas, and agricultural industrial areas. Another 71,818 acres (28,727 hectares) are in drains, canals, rivers, railroads, and roads. Urban recreation areas (both parks and lakes), and rural schools account for 12,498 acres (5,000 hectares). The remaining acreage is mostly in undeveloped land.

The East Highline Canal trends along the sea level contour. The All-American Canal, along the U.S.-Mexican border, drops from 35 feet (10 meters) above sea level at the junction with the East Highline Canal to 10 feet (3 meters) below sea level at the junction with the Westside Main Canal. The Westside Main Canal drops from 10 feet (3 meters) below sea level at the international border to 175 feet (52 meters) below sea level in the northwest corner of the valley. The lowest elevation in the valley is the southern shoreline of the Salton Sea which fluctuates between -231 feet (-69 meters) and -234 feet (-70 meters). The high water level occurs in April and the low water mark in October. Contour lines reveal a gentle slope from the southeast corner to the northwest corner.

The slope has an average fall of 7 feet per mile (2.1 meters per km). The northeast corner near Niland, however, is steeply sloping with an average fall of 80 feet per mile (24.4 meters per km).

2. Climate

The climate is sub-tropical arid.[7] Slightly less than 3 inches (76 mm) of annual average rainfall occurs between August and April with 0.75 inch (19 mm) occurring in August and September as summer thunderstorms or "cloudbursts." The effect of this meager rain is slight as reflected by the barren desert surrounding the valley. Consequently, moisture content of soil and fields is controlled entirely through irrigation which provides a completely artificial moisture environment for the study area. Table VI outlines the Valley's climate data. Normal mean annual temperature of 72°F (22.2°C) only hints at the extreme summer temperatures. The mean daily maximum temperatures during the months of June through September ranges from 103°F (39.4°C) to 108°F (42.2°C) with daily maximums of 115°F (46.1°C) being normal and random maximums of 122°F (50.4°C) not uncommon. High evaporation rates, over 12 inches (30 cm) for one summer month, help account for the stable level of the Salton Sea even though the sea is a catchment for all excess irrigation water.

From the time the first irrigation waters flowed into the valley on June 21, 1901 the area has presented an ideal site for study of isolated agricultural land use. Lush fields present a striking contrast to barren desert as many satellite photos have shown. Except for three winter

[7]The climate is classified as sub-tropical rather than tropical even though the mean of the coldest month is over 50°F because frost occurs in more than 40 nights during the winter.

TABLE VI-1 CLIMATIC DATA FOR THE IMPERIAL VALLEY

Section 1. Annual Normals

	Brawley	Calexico	El Centro	Imperial
Average Frost Free Days	317		316	
Mean Date of First Frost	Dec. 11		Dec. 28*	Dec. 28*
Mean Date of Last Frost	Jan. 28		Jan. 31*	Jan. 23*
Actual Number of Frost Nights	48	37	42	51
Mean Number of Days 90°F or over	182		183	177
Mean Number of Days 90°F or under	7		15	5
Highest Temperature	122(50.4°C)	117(47.6°C)	122(50.4°C)	117(47.6°C)
Mean Max. Temp.	88.3(31.5°C)	86.4(30.5°C)	89.6(32.3°C)	88.2(31.5°C)
Mean Min. Temp.	55.6(13.2°C)	55.7(13.2°C)	55.9(13.4°C)	56.8(13.9°C)
Record Mean	71.9(22.3°C)	71.0(21.8°C)	72.8(22.9°C)	72.6(22.7°C)
Lowest	19(-7.3°C)	21(-6.2°C)	16(-9.0°C)	26(-3.4°C)
Degree Days (Nov-Mar)	1216		1137	1086
Degree Days (Apr-Oct)	16		8	3
Mean Annual Precipitation	2.57(65.3mm)	2.93(74.4mm)	2.81(71.4mm)	2.84(72.1mm)
Average Number of Days .01 Precip. or more (0.25mm)	11	13	15	
Average Number of Days .10 Precip. or more (2.54mm)	2	2	6	5
Average Number of Days .50 Precip. or more	0	0	0	0

*1966 ONLY

TABLE VI-2 CLIMATIC DATA FOR THE IMPERIAL VALLEY
(Temperatures in °F, Precipitation in inches)

Section 2. Monthly Normals

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Brawley												
Highest Temp	87	91	104	108	118	118	122	120	121	111	98	122
Mean Max Temp	68.4	73.2	79.0	86.7	94.7	103.2	107.8	106.6	101.8	90.4	78.6	69.5
Mean Min Temp	37.5	41.7	47.8	53.7	60.3	66.9	75.4	75.7	68.7	56.5	44.6	38.9
Mean Temp	53.0	56.2	63.4	70.3	77.4	85.2	91.6	91.1	85.2	73.5	61.6	54.1
Lowest Temp	19	25	29	35	41	49	55	59	50	34	26	20
Mean Precip	0.35	0.36	0.19	0.11	0.04	0.02	0.05	0.23	0.25	0.24	0.14	0.59
Calexico												
Highest Temp	85	93	100	104	116	117	117	117	113	106	99	89
Mean Max Temp	67.5	73.3	78.6	85.5	92.2	101.3	103.9	103.4	98.6	88.0	76.7	67.3
Mean Min Temp	38.9	43.4	47.7	53.3	58.7	67.4	75.9	74.5	67.7	56.0	45.7	39.0
Mean Temp	53.2	58.4	63.2	69.4	75.3	84.3	89.8	89.0	83.2	72.0	61.1	53.2
Lowest Temp	21	28	32	39	41	54	59	55	48	36	28	23
Mean Precip	0.47	0.41	0.24	0.08	0.04	0.02	0.08	0.53	0.20	0.18	0.24	0.44
El Centro												
Highest Temp	86	90	102	109	116	121	122	122	120	112	96	92
Mean Max Temp	69.1	73.3	80.5	88.3	96.0	104.0	109.2	107.7	103.6	92.2	80.0	71.4
Mean Min Temp	37.8	41.7	47.2	53.7	60.7	66.7	75.2	75.6	69.0	57.5	45.2	40.2
Mean Temp	53.4	57.5	63.8	71.0	78.3	85.3	92.2	91.7	86.3	75.1	62.6	55.8
Lowest Temp	16	23	29	33	44	47	52	58	52	39	26	24
Mean Precip	0.30	0.46	0.23	0.07	T	0.02	0.10	0.30	0.38	0.25	0.08	0.62
Imperial												
Highest Temp	86	92	93	103	111	117	117	115	113	108	92	90
Mean Max Temp	69.7	73.4	78.6	85.9	93.3	102.5	106.6	104.5	102.7	91.6	78.1	71.1
Mean Min Temp	41.1	44.1	48.6	55.5	61.3	69.0	77.2	76.6	71.5	60.5	47.4	41.6
Mean Temp	54.1	58.0	63.6	70.9	77.8	85.1	91.8	90.8	86.0	74.8	62.3	55.9
Lowest Temp	26	29	33	41	47	53	63	60	54	44	32	26
Mean Precip	0.37	0.43	0.18	0.14	0.01	0.00	0.07	0.40	0.37	0.27	0.11	0.49

months the valley is almost 100% cloud free and these three winter months
months the valley is almost 100% cloud free and these three winter months
have more than 80% of the possible sunshine. Target timetables for imaging
have more than 80% of the possible sunshine. Target timetables for imaging
overflights will seldom have any problems with cloud cover.
overflights will seldom have any problems with cloud cover.

Appendix B

Interpretation, Mapping, and Analysis Procedures

Traditionally, land use mapping has been a long, tedious, manual process. Attempts are being made to reduce the task to a completely automatic process through the use of image or analysis equipment. The previously mentioned individual crop color variations often prevent automatic equipment from achieving satisfactory results. One may speculate that this problem will require some agricultural fields to always be examined individually. In fact, individual field examination is the basis for the system described. It is a system which can evolve from a manual method and be developed into a semiautomatic and perhaps automatic system. The system is not completely dependent on color signatures but takes advantage of environmental factors as well as other information available about agricultural practices in the study area. Basically, the process requires data to be read from the image by a human equipment operator, fed to the computer, and the computer (on the basis of information previously provided) will determine the type of land use. The procedure is:

(1) Prepare base map,

(2) Establish Crop Calendar for the date of the imagery,

(3) Overlay base map on imagery or project imagery onto the base map,

(4) Establish Crop Signature color values from ground survey test fields,

(5) Determine and record field location,

(6) Determine and record field color values by use of color i.e., densitometer or similar device,

(7) Perform computer crop identification,

(8) Prepare final agricultural land use map i.e., manually or by computer graphics.

Additional comments and discussion of the eight basic steps:

1. Base Map Preparation

Preparation of the local base map has been previously discussed.

2. Development of Crop Calendar for the Date of the Image

One of the more important steps in delimiting the number of crops which must be examined is to determine those crops under cultivation on the date of the imagery. The calendar is best established from the annual crop calendar for the local agricultural area being examined. (Table VII, is a List of Major Crops Under Cultivation on March 12 prepared for the date of the Apollo 9 photo of the Imperial Valley.) In the Imperial Valley there are approximately 48 different crops being cultivated throughout the year, but seldom are there more than half of these under cultivation at any one time. Crop calendars must be used with caution since they are only a "close approximation" of the average conditions and a shift in climate or market conditions can alter cultivation or harvesting plans. (i.e., sugar beets are shown on the Imperial Valley crop calendar as being completely harvested by mid-July. Yet in 1969 there were still sugar beets in the ground on the last day of July. This was caused by a three week trucker strike and mechanical failure in the Union Sugar Plant. In 1968, the planting of cotton was delayed 6 to 8 weeks because of predicted insect invasion.)

3. Image Projection or Base Map Overlay

Many errors have occurred and much time has been lost in performing land use mapping from imagery by attempting to view the image transparency

TABLE VII

List of Major Crops
Under Cultivation on March 12 in Imperial Valley
(From the Crop Calendar of the Imperial Valley)

A. Crops Showing Vegetative Cover

Field Crops

111 Barley (Mid-Season Stage)

118 Wheat (Mid-Season Stage)

131 Short Grasses (Rye, Bermuda)

133 Alfalfa

142 Sugar Beets (Near Full Maturity)

172 Flax (Blooming)

Vegetable Crops

211 Asparagus (Being Harvested)

231 Lettuce (Harvested, Being Plowed Under)

232 Celery

272 Carrots (End of Harvest Season)

282 Garlic

284 Onions (Under Harvest)

Fruit and Nut Crops

330 Citrus Fruit, Undifferentiated

342 Dates

363 Pecans (Blooming)

B. Crops Planted or Seeded and Irrigated, but Not Showing Vegetative Cover

Field Crops

114 Grain Sorghum (Planting Season One Week Old)

131 Tall Grasses (Sudan) (Planting Season Two Weeks Old)

151 Cotton (Fields Prepared, but Not Yet Seeded)

Vegetable Crops (Fields Seeded and Irrigated)

250 Melons, Undifferentiated

251 Cantaloupes (Planted with Caps On)

256 Watermelons (Planted with Caps On)

263 Tomatoes (Planted)

on a separate light table and transfer the interpreted data to some location on a base map. Efficient manual or automatic processing dictates that the image and the map be made coincident. Several methods exist for accomplishing this technique either by projecting the image onto the base map or overlaying the base map on the image depending which is larger and which system is more convenient. Several map-image projectors are on the market that can accomplish the coincidence and utilizing x-y recording plotters which can be programmed to read particular map coordinates from the image. The latter devices can be used to develop an automatic readout system. Plate 1 illustrates the method used in this study to project the image on the base map for interpretation of the Apollo 9 imagery of the Imperial Valley. Bringing the image into register with the base map was accomplished and slight rectification of the field patterns in each of the four quadrants of the map made the map and image coincident. An image edge enhancement resulted that permitted the eye to distinguish individual field colors which in the image alone often blended with the color of adjacent fields making precise determination difficult to achieve.

When the image and projections are planimetrically different, some difficulty will be experienced in registering a projected image onto a base map. Aerial photographic images are essentially orthographic map projections in which the distortion increases radially from the center of the image. The USGS topographic control map used and many maps used for similar studies are polyconic or like projections in which the distortion begins at a central meridian and increase outward in an east-west or north-south direction but not omni-directional. The disparities would be

small over small areas of the earth, but increase as the area increases. The enlarged 70 mm. Apollo photograph, covering an area approximately 100 miles (161 km) on each side, required very little rectification to bring it into register with the base map.

4. Establishing Crop Color Signature from Ground Survey Data

Sufficient research and experimental data has not been obtained to establish uniform crop color signature values at present. The values will have to be established from the imagery being analyzed. Enough information has been obtained to establish gross relative color differences between crop types, but it still is necessary to establish a single reference level of color tone from the particular imagery being analyzed. However, the task is not insurmountable. Initial color densitometric readings taken of a new set of imagery should be of ground survey test sites. The test fields will serve as the "training" areas for the interpreter (manual or automatic). Data from these readings can then be used to establish the color values placed in the Crop Signature tables of the computer program for crop identification.

5. Determine and Record Individual Field Location

The dual coordinate system established on the local base map as previously described permits two methods of field location to be entered into the computer data. When image data reduction is being performed manually, the field location can be recorded by the less complex local grid system. When data readout is being performed by use of x-y coordinate equipment, it may be desirable to record the geographic coordinates of the field which provides the computer with sufficient data to perform acreage calculations.

6. Determine and Record Individual Field Color Values

To maintain color consistency, color measurements should be performed with a color photo densitometer or similar device. An arrangement should bemade whereby, if three color readings are necessary for each field, they should bemade at the same time that the field coordinates are obtained. The three readings must all be of an identical spot using the different color separation filters (green, red, and blue) of the densitometer. Regular photo densitometers have spot sizes from 1 to 4 mm. If the field size is more than 5 times larger (15-25 mm.) than the densitometer spot size, it may be prudent to take at least three separate spot readings in a field and average color values.

7. Perform Computer Crop Identification

The above procedures have been designed so that recorded data for each field may be provided as a computer input for subsequent identification. To perform computer identification, pre-programming of the computer with identification tables is necessary. A minimum number and size of table can be achieved by utilizing the local crop calendar. The crop calendar consolidates most of the cultural and physical environmental factors into a concise list of the type of crops grown in the area and the dates these crops can possibly be grown. In the past, interpreters have qualitatively used the crop calendar in their work, but in establishing a computer program a more concious effort must be employed to insure consideration of all factors and reduce expensive processing time. Utilizing a table search method for computer identification, the procedure may logically begin with the most important factor in CIR

imagery - the crop color. The color tone is matched as loosely as possible to those provided by the color table and a tentative identification established. As the environmental determinants have been considered in the crop calendar, the only other table necessary in the computer processing is a table of farming practice factors.

Resolution and available detail on the image will determine how many farming pattern factors can be used. Normally field size and shape will be available to help differentiate between crops. Other factors, such as number of rows per given distance or width of flood borders, will provide further delimiting information. If sequential imagery has been obtained and recorded for the area, referral to previous crop type may help to determine plausibility of the tentatively identified crop. For example, in the Imperial Valley, the cotton crop is not picked until after mid--October and since sugar beets must be planted before this date, it is not plausible that sugar beets would follow a cotton crop. Other similar crop rotations exist and are a helpful delimiter in crop identification.

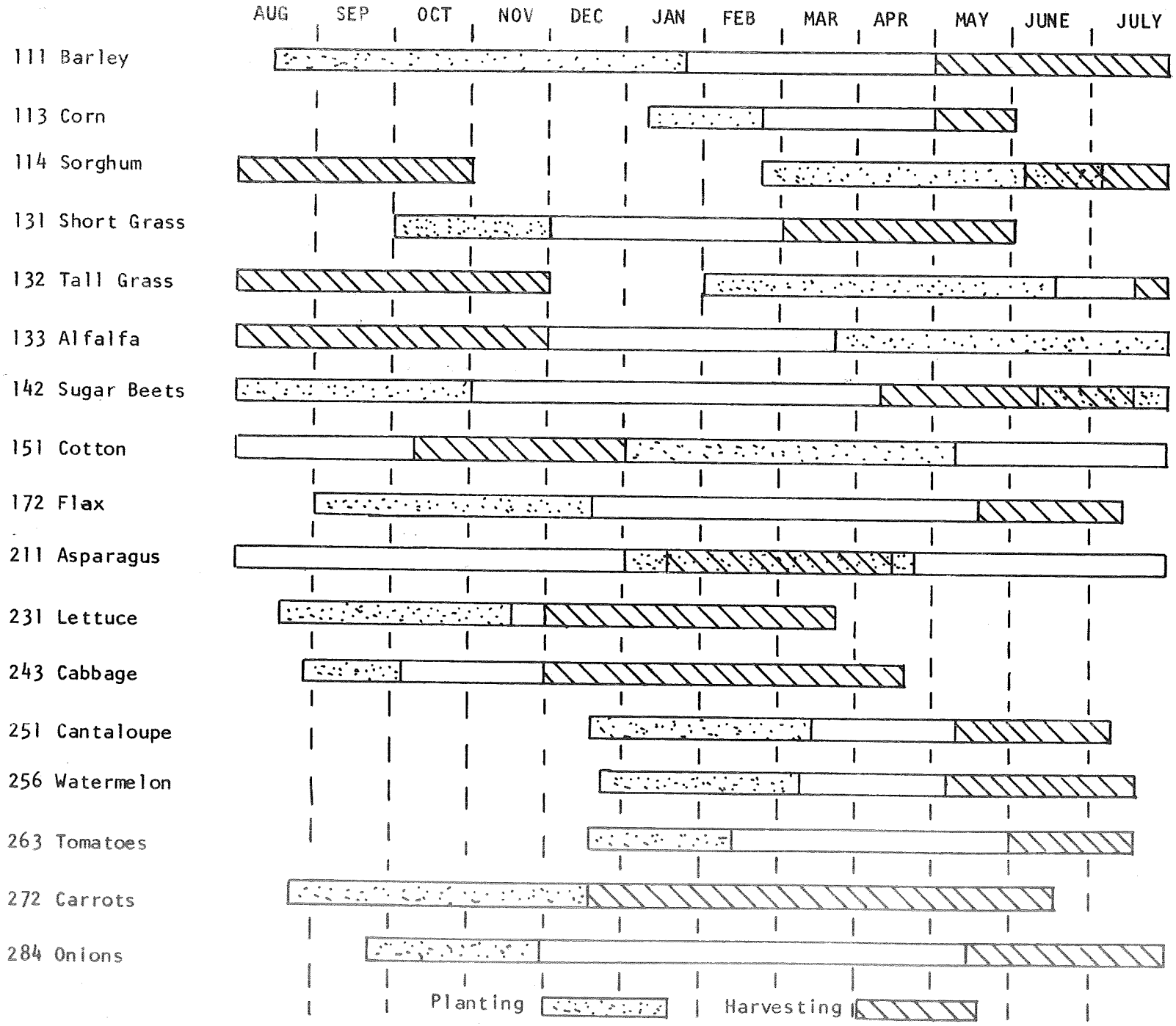
There will usually be crops which the computer identification will indicate as two or three possibilities. The program may be designed to show weighted possibilities with the best choice indicated. Hopefully, few identification problems will force the interpreter to give individual attention before a final decision can be made. Based upon previous experience with other types of computer identification systems, unidentified crops should be about 3%.

8. Prepare Final Agricultural Land Use Map and Statistical Data

Two normally desired outputs, a statistical map and summary, can both be accomplished by a computer. A statistical summary printout can be prepared in almost any form desired. Section V lists a few such summaries. Computer mapping is not quite as common, but with the advent of computer graphics, more and more map displays will be produced. Current geographical computer mapping is being accomplished mostly by line printing using different symbols to produce a form of choropleth map which is not entirely satisfactory for land use mapping. With the aid of computer auxiliary equipment such as the Calcomp Plotter, a regular outline map can be prepared with the land use code indicated in each field.

A compromise between a completely computer prepared map and a completely hand drawn map, is to have the computer plotting paper produced with the outline base map as a background. Using the locally devised grid system, the computer plotter can then be instructed to insert the agricultural land use code in the appropriate fields. The advantage of the latter system is the ease with which a series of topical maps can be prepared for each crop type or crop class for study of distribution patterns. Preparation of such topical maps would also provide valuable support to the image enhancement and analysis equipment investigations providing the necessary target patterns for matching distinct color patterns of the enhancement equipment. (See Appendix D)

APPENDIX C-1 CROP CALENDAR FOR THE IMPERIAL VALLEY



APPENDIX C-2 AGRICULTURAL LAND USE CODE

(A HORTICULTURAL/AGRONOMIC CLASSIFICATION)

5 DIGIT CODE LISTING

8 RESOURCE PRODUCTION AND EXTRACTION

80000 RESOURCE PRODUCTION AND EXTRACTION, UNDIFFERENTIATED

81 AGRICULTURE

81000 AGRICULTURE, UNDIFFERENTIATED

811 FIELD AND SEED CROPS (EXTENSIVE FARMING)

8110 UNDIFFERENTIATED FIELD AND SEED CROPS

81100 FIELD AND SEED CROPS, UNDIFFERENTIATED

8111 CEREAL AND GRAIN CROPS

81110 CEREAL AND GRAIN CROPS, UNDIFFERENTIATED
81111 BARLEY
81112 BUCKWHEAT
81113 CORN(MAIZE)
81114 SORGHAM, GRAIN
81115 OATS
81116 RICE
81117 RYE
81118 WHEAT
81119 CEREAL AND GRAIN CROPS, OTHER DIFFERENTIATED

8112 LEGUMES FOR SEED CROPS

81120 LEGUMES FOR SEED)DRY*, UNDIFFERENTIATED
81121 BEANS, FIELD (DRIED BEFORE HARVEST)
81122 PEAS, FIELD (DRIED BEFORE HARVEST-INCLUDES-CHICKPEAS +COWPEAS
81123 LENTILS
81124 BEANS, LIMA (DRIED BEFORE HARVEST)
81125 PEANUTS
81126 SOYBEAN (FOOD)
81127
81128
81129 LEGUMES FOR SEED)DRY*, OTHER DIFFERENTIATED

8113 FORAGE CROPS (NON GRAINS)

81130 FORAGE CROPS, UNDIFFERENTIATED
81131 GRASSES, SHORT (I.E. BERMUDA, BLUEGRASS, TIMOTHY, ETC.)
81132 GRASSES, TALL (I.E. SUDAN/SORGHAM, CORN, ETC)
81133 LEGUMES (I.E. ALFALFA, CLOVER, VETCH, ETC.)
81134 ROOTS (I.E. JERUSALEM ARTICHOKES, MANGELS(BEETS),ETC.)
81135
81136
81137
81138
81139 FORAGE CROPS, OTHER DIFFERENTIATED

8114 SUGAR CROPS
- 81140 SUGAR, CROPS, UNDIFFERENTIATED
- 81141 SUGAR CANE
- 81142 SUGAR BEETS
- 81143
- 81144
- 81145
- 81146
- 81147
- 81148
- 81149 SUGAR CROPS, OTHER DIFFERENTIATED FIELD CROPS

8115 FIBER CROPS
- 81150 FIBER CROPS, UNDIFFERENTIATED
- 81151 COTTON
- 81152 FIBER FLAX
- 81153 HEMP
- 81154 JUTE
- 81155 MILKWEED
- 81156 RAFFIA
- 81157 RAMIE
- 81158 RATTAN
- 81159 FIBER CROPS, OTHER DIFFERENTIATED

8116 BEVERAGE,DRUG, FLAVORING, OR SPICE CROPS
- 81160 BEVERAGE, SPICE, FLAVORING OR DRUG CROPS, UNDIFFERENTIATED
- 81161 BEVERAGE CROPS, UNDIFFERENTIATED
- 81162 COACO
- 81163 COFFEE
- 81164 TEA
- 81165 BEVERAGE CROPS, OTHER DIFFERENTIATED
- 81166 SPICE CROPS
- 81167 FLAVORING CROPS
- 81168 DRUG CROPS
- 81169 BEVERAGE, DRUG, FLAVORING, OR SPICE CROP, OTHER DIFFERENTIATE

8117 OIL CROPS
- 81170 OIL CROPS, UNDIFFERENTIATED
- 81171 CASTOR BEAN
- 81172 FLAX, SEED
- 81173 PERRILLA
- 81174 SAFFLOWER
- 81175 SESAME
- 81176 SOYBEAN (OIL)
- 81177
- 81178
- 81179 OIL CROPS, OTHER DIFFERENTIATED

8118 RUBBER CROPS
- 81180 RUBBER CROPS, UNDIFFERENTIATED FIELD
- 81181 GUAYULE
- 81182 KOK-SAGYZ
- 81183
- 81184

81185
81186
81187
81188
81189 RUBBER CROPS, OTHER DIFFERENTIATED

8119 OTHER DIFFERENTIATED FIELD AND SEED CROPS
81190 FIELD AND SEED CROPS, OTHER DIFFERENTIATED

812 VEGETABLE CROPS (INTENSIVE FARMING)

8120 UNDIFFERENTIATED VEGETABLE CROPS
81200 VEGETABLE CROPS, UNDIFFERENTIATED

8121 PERENNIAL VEGETABLE CROPS
81210 PERENNIAL VEGETABLE CROPS, UNDIFFERENTIATED
81210 VEGETABLE CROPS, PERENNIAL, UNDIFFERENTIATED
81211 ASPARAGUS
81212 ARTICHOKE, GLOBE
81213 HORSERADISH
81214 RHUBARB
81215
81216
81217
81218
81219 PERENNIAL VEGETABLE CROPS, OTHER DIFFERENTIATED
81219 VEGETABLE CROPS, PERENNIAL, OTHER DIFFERENTIATED

8122 GREEN LEGUME (POD) CROPS
81220 LEGUME CROPS, GREEN, UNDIFFERENTIATED
81221 BEANS, GREEN (SNAP, POLE, KENTUCKEY WONDERS, STRING, ETC)
81222 BEANS, GREEN LIMA
81223 PEAS, GREEN
81224 OKRA
81225 BLACK EYED PEAS (CANNED GREEN)
81226
81227
81228
81229 LEGUME CROPS, GREEN, OTHER DIFFERENTIATED

8123 SALAD AND GREENS CROPS
81230 SALAD AND GREENS CROPS, UNDIFFERENTIATED
81231 LETTUCE (SALAD)
81232 CELERY (SALAD)
81233 CRESS (SALAD)
81234 PARSLEY (SALAD)
81235 CHINESE CABBAGE (SALAD)
81236 CHARD AND KALE (GREENS)
81237 MUSTARD GREENS
81238 SPINACH GREENS
81239 SALAD AND GREEN CROPS, OTHER UNDIFFERENTIATED

8124 COLE CROPS
81240 COLE CROPS, UNDIFFERENTIATED
81241 BROCCOLI
81242 BRUSSELS SPROUTS
81243 CABBAGE
81244 CAULIFLOWER
81245 COLLARDS
81246 KOHLRABI
81247
81248
81249 COLE CROPS, OTHER DIFFERENTIATED

8125 CURCURITS (VINE) CROPS
81250 CURCURITS (VINE* CROPS, UNDIFFERENTIATED
81251 CANTALOUPES
81252 CUCUMBERS
81253 MELONS (OTHER THAN CANALOUPES)
81254 PUMPKINS
81255 SQUASHES
81256 WATERMELONS
81257
81258
81259 OTHER DIFFERENTIATED CURCURITS (VINE) CROPS

8126 SOLANACEOUS CROPS
81260 SOLANACEOUS CROPS, UNDIFFERENTIATED
81261 EGGPLANT
81262 PEPPERS
81263 TOMATOES
81264
81265
81266
81267
81268
81269 SOLANACEOUS CROPS, OTHER DIFFERENTIATED

8127 ROOT AND TUBER CROPS
81270 ROOT AND TUBER CROPS, UNDIFFERENTIATED
81271 BEETS (OTHER THAN SUGAR BEETS)
81272 CARROTS
81273 PARSNIPS
81274 POTATOES (TUBER)
81275 RADISHES
81276 RUTABAGAS
81277 SWEET POTATOES
81278 TURNIPS
81279 ROOT AND TUBER CROPS, OTHER DIFFERENTIATED

8128 BULB CROPS
81280 BULB CROPS, UNDIFFERENTIATED
81281 CHIVES
81282 GARLIC
81283 LEAKS
81284 ONIONS
81285
81286
81287
81288
81289 BULB CROPS, OTHER DIFFERENTIATED

8129 OTHER DIFFERENTIATED VEGETABLE CROPS
81290 VEGETABLE CROPS, OTHER DIFFERENTIATED

813 FRUIT AND NUT CROPS

8130 UNDIFFERENTIATED FRUITS OR NUTS
81300 FRUIT AND NUT CROPS, UNDIFFERENTIATED

8131 SMALL FRUITS
81310 FRUITS, SMALL, UNDIFFERENTIATED
81310 SMALL FRUITS, UNDIFFERENTIATED
81311 BRAMBLES (BLACKBERRY,DEWBERRY,BOYSONBERRY,RASPBERRY)
81312 BLUBERRY(HUCKLEBERRY) AND CRANBERRY
81313 CURRANT AND GOOSBERRY
81314 GRAPES
81315 STRAWBERRIES
81316
81317
81318
81319 FRUIT, SMALL, OTHER DIFFERENTIATED
81319 SMALL FRUIT, OTHER DIFFERENTIATED

8132 DECIDUOUS TREE FRUITS
81320 DECIDUOUS TREE FRUIT, UNDIFFERENTIATED
81320 FRUIT, TREE, DECIDUOUS, UNDIFFERENTIATED
81321 APPLE (INCLUDES- CRABAPPLE AND QUINCE)
81322 APRICOT
81323 CHERRY
81324 FIG
81325 NECTARINE
81326 PEACH
81327 PEAR
81328 PLUM)INCLUDES9 PRUNE*
81329 DECIDUOUS TREE FRUIT, OTHER DIFFERENTIATED
81329 FRUIT, TREE, DECIDUOUS, OTHER DIFFERENTIATED

8133 CITRUS TREE FRUITS
81330 CITRUS TREE FRUIT, UNDIFFERENTIATED
81331 GRAPEFRUIT
81332 KUMQUAT
81333 LEMON
81334 LIME
81335 ORANGE
81336 TANGELO
81337 TANGERINE
81338
81339 CITRUS TREE FRUIT, OTHER DIFFERENTIATED

8134 MISCELLANEOUS EVERGREEN TREE FRUIT
81340 EVERGREEN TREE FRUIT, UNDIFFERENTIATED
81340 FRUIT, TREE, EVERGREEN, UNDIFFERENTIATED
81341 AVACADO
81342 DATE
81343 MANGO
81344 OLIVE
81345 PAPAYA
81346

81347
81348
81349 EVERGREEN TREE FRUIT, OTHER DIFFERENTIATED
81349 FRUIT, TREE, EVERGREEN, OTHER DIFFERENTIATED

8135 HERBACEOUS PERENNIAL FRUITS
81350 FRUIT, PERENNIAL, HERBACEOUS, UNDIFFERENTIATED
81350 HERBACEOUS PERENNIAL FRUIT, UNDIFFERENTIATED
81351 BANANA
81352 GUAVA
81353 PINAPPLE
81354
81356
81357
81358
81359 FRUIT, PERENNIAL, HERBACEOUS, OTHER DIFFERENTIATED
81359 HERBACEOUS PERENNIAL FRUIT, OTHER DIFFERENTIATED

8136 DECIDUOUS NUTS
81360 DECIDUOUS NUTS, UNDIFFERENTIATED
81360 NUTS, DECIDUOUS, UNDIFFERENTIATED
81361 ALMOND
81362 FILBERT (HAZELNUT)
81363 PECAN
81364 PISTACHIO
81365 WALNUT
81366 NUTMEG
81367
81368
81369 DECIDUOUS NUTS, OTHER DIFFERENTIATED
81369 NUTS, DECIDUOUS, OTHER DIFFERENTIATED

8137 EVERGREEN NUTS
81370 EVERGREEN NUTS, UNDIFFERENTIATED
81370 NUTS, EVERGREEN, UNDIFFERENTIATED
81371 BRAZIL
81372 CASHEW
81373 COCONUT
81374 LITCHI (LYCHEE)
81375 MACADAMIA
81376
81377
81378
81379 EVERGREEN NUTS, OTHER DIFFERENTIATED
81379 NUTS, EVERGREEN, OTHER DIFFERENTIATED

8138

8139 OTHER DIFFERENTIATED FRUIT AND NUT CROPS
81390 FRUIT AND NUT CROPS, OTHER DIFFERENTIATED

814 LIVESTOCK

8140 UNDIFFERENTIATED LIVESTOCK
81400 LIVESTOCK, UNDIFFERENTIATED

8141 BEEF CATTLE (OTHER THAN DAIRY-INCLUDES FEED LOTS)
81410 BEEF CATTLE (OTHER THAN DAIRY- INCLUDES FEED LOTS)

8142 HORSES
81420 HORSES

8143 SWINE
81430 SWINE

8144 DAIRIES AND DAIRY FEEDING
81440 DAIRIES AND DAIRY FEEDING

8145 SHEEP
81450 SHEEP

8146 GOAT
81460 GOAT

8147
8148

8149 OTHER DIFFERENTIATED LIVESTOCK
81490 LIVESTOCK, OTHER DIFFERENTIATED

815 ANIMAL SPECIALTIES

8150 UNDIFFERENTIATED SMALL ANIMAL PRODUCTION
81500 ANIMAL PRODUCTIONS, SMALL, UNDIFFERENTIATED

81500 SMALL ANIMAL PRODUCTION, UNDIFFERENTIATED

8151 CHICKEN (MEAT)
81510 CHICKEN (MEAT)

8152 CHICKEN (EGG)
81520 CHICKEN (EGG PRODUCTION)

8153 TURKEY
81530 TURKEY

8154 OTHER DIFFERENTIATED POULTRY
81540 POULTRY, OTHER DIFFERENTIATED

8155 RABBITS
81550 RABBITS

8156 APARIES
81560 APARIES

8157
8158

8159 OTHER DIFFERENTIATED ANIMAL SPECIALTIES
81590 ANIMAL SPECIALTIES, OTHER DIFFERENTIATED

816 PASTURE AND RANGELAND

8160 UNDIFFERENTIATED PASTURE AND RANGELAND
81600 PASTURE AND RANGELAND, UNDIFFERENTIATED

8161 PASTURE
81610 PASTURE

8162 RANGELAND
81620 RANGELAND

817 HORTICULTURAL SPECIALTIES

8170 UNDIFFERENTIATED HORTICULTURAL SPECIALTIES
81700 HORTICULTURAL SPECIALTIES, UNDIFFERENTIATED

8171 CUT FLOWERS STOCK, COVERED
81710 FLOWERS, COVERED CUT STOCK

8172 CUT FLOWERS STOCK, OPEN FIELD
81720 FLOWERS, OPEN FIELD CUT STOCK

8173 OTHER DIFFERENTIATED NURSARY STOCK
81730 NURSARY STOCK, OTHER DIFFERENTIATED

8174
8175
8176
8177
8178

8179 OTHER DIFFERENTIATED HORTICULTURAL SPECIALTIES
81790 HORTICULTURAL SPECIALTIES, OTHER DIFFERENTIATED

818 NON-PRODUCING AND TRANSITION CROP LAND

8180 UNDIFFERENTIATED NON-PRODUCING CROP LAND
81800 NON-PRODUCING CROP LAND, UNDIFFERENTIATED

8181 FALLOW CROP LAND
81810 FALLOW CROP LAND (NON-GROWING, NON-PASTURE, OR BARE)

8182 PLOWED CROP LAND
81820 PLOWED CROP LAND

8183 LEACHED CROP LAND
81830 LEACHED CROP LAND

8184 ABANDONED CROP LAND (TREE, VINE, HERBACEOUS, GRASS, FIELD, ETC.)
81840 ABANDONED CROP LAND (TREE, VINE, HERBACEOUS, GRASS, FIELD, ET

8185 HARVESTED FIELD (STUBBLE, INCLUDES CROP LAND OPEN TO CATTLE GRAZIN
81850 HARVESTED FIELD (STUBBLE, INCLUDES CROP LAND OPEN TO CATTLE)

8186 PREPARED CROP LAND (READY FOR SEEDING, OR SEEDED, AND/OR IRRIGATED
81860 PREPARED LAND (READY FOR SEEDING, OR SEEDED, AND/OR IRRIGATED

8187
8188

8189 OTHER DIFFERENTIATED NON-PRODUCING CROP LAND
81890 NON-PRODUCING CROP LAND, OTHER DIFFERENTIATED

819 OTHER AGRICULTURAL ACTIVITY

8190 UNDIFFERENTIATED OTHER AGRICULTURAL ACTIVITY
81900 AGRICULTURAL ACTIVITIES, OTHER, UNDIFFERENTIATED
81900 OTHER AGRICULTURAL ACTIVITY, UNDIFFERENTIATED

8191 TREE FARMS
81910 TREE FARMS

8199 OTHER DIFFERENTIATED OTHER AGRICULTURAL ACTIVITIES
81990 OTHER AGRICULTURAL ACTIVITIES, OTHER DIFFERENTIATED

82 AGRICULTURAL RELATED ACTIVITIES

8200 UNDIFFERENTIATED AGRICULTURAL RELATED ACTIVITIES
82000 AGRICULTURAL RELATED ACTIVITIES, UNDIFFERENTIATED

821 AGRICULTURAL PROCESSING

8210 UNDIFFERENTIATED AGRICULTURAL PROCESSING
82100 AGRICULTURAL PROCESSING, UNDIFFERENTIATED

8211 COTTON GINNING AND COMPRESSING
82110 COTTON GINNING AND COMPRESSING

8212 GRIST MILLING SERVICES

82120 GRIST MILLING SERVICES

8213 CORN SHELLING, HAY BALING, THRESHING SERVICES
82130 CORN SHELLING, HAY BALING, THRESHING SERVICES

8214 CONTRACT SORTING, GRADING, AND PACKAGING SERVICES
82140 CONTRACT SORTING, GRADING, AND PACKAGING SERVICES

8215 EGG PROCESSING
82150 EGG PROCESSING

8216
8217
8218

8219 OTHER DIFFERENTIATED AGRICULTURAL PROCESSING SERVICES
82190 AGRICULTURAL PROCESSING SERVICES, OTHER DIFFERENTIATED

822
823
824
825
826
827
828

829 OTHER AGRICULTURAL RELATED SERVICES

8290 OTHER AGRICULTURAL RELATED SERVICES, UNDIFFERENTIATED
82900 AGRICULTURAL RELATED SERVICES, OTHER, UNDIFFERENTIATED
82900 OTHER AGRICULTURAL RELATED SERVICES, UNDIFFERENTIATED

8291

8292 SPRAYING, DUSTING, PRUNING, PLANTING, TREE SURGERY
82920 SPRAYING, DUSTING, PRUNING, PLANTING, TREE SURGERY

8293 HORTICULTURAL SERVICES)INCLUDES - EXPERIMENTAL STATIONS*
82930 HORTICULTURAL SERVICES (INCLUDES-EXPERIMENTAL STATIONS)

8294
8295
8296
8297
8298

8299 OTHER DIFFERENTIATED OTHER AGRICULTURAL RELATED SERVICES
82990 AGRICULTURAL RELATED SERVICES, OTHER DIFFERENTIATED
82990 OTHER AGRICULTURAL RELATED SERVICES, OTHER DIFFERENTIATED

1 UNDEVELOPED AND UNUSED LAND AREA

91 UNDEVELOPED AND UNUSED LAND AREA

910 UNDEVELOPED AND UNUSED LAND AREA

9100 UNDIFFERENTIATED UNDEVELOPED AND UNUSED LAND AREA

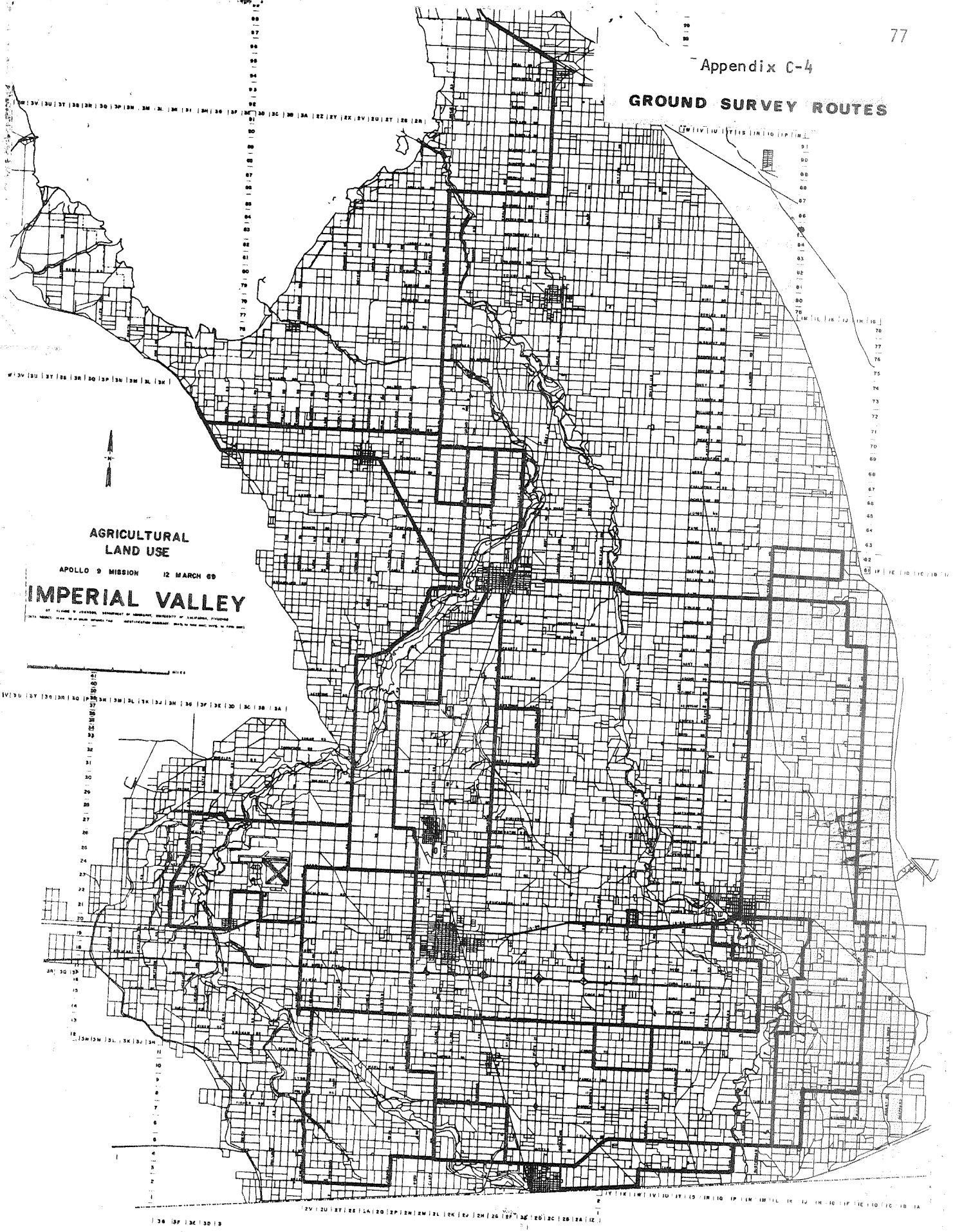
91000 UNDEVELOPED AND UNUSED LAND AREA, UNDIFFERENTIATED

Appendix C-3 Agricultural Land Use Map of Imperial Valley

(This appendix will be found in the inside pocket of the back cover).

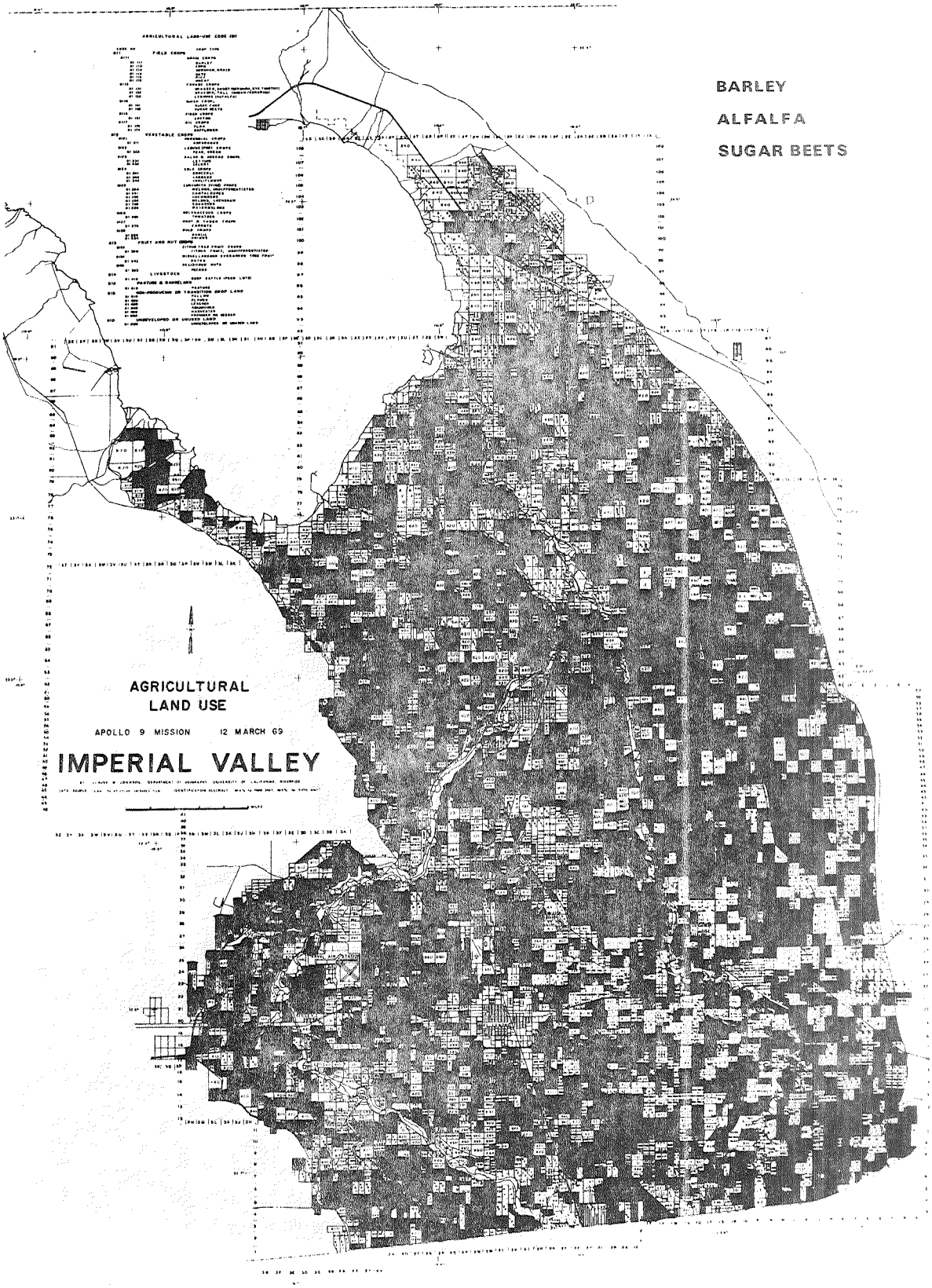
Appendix C-4

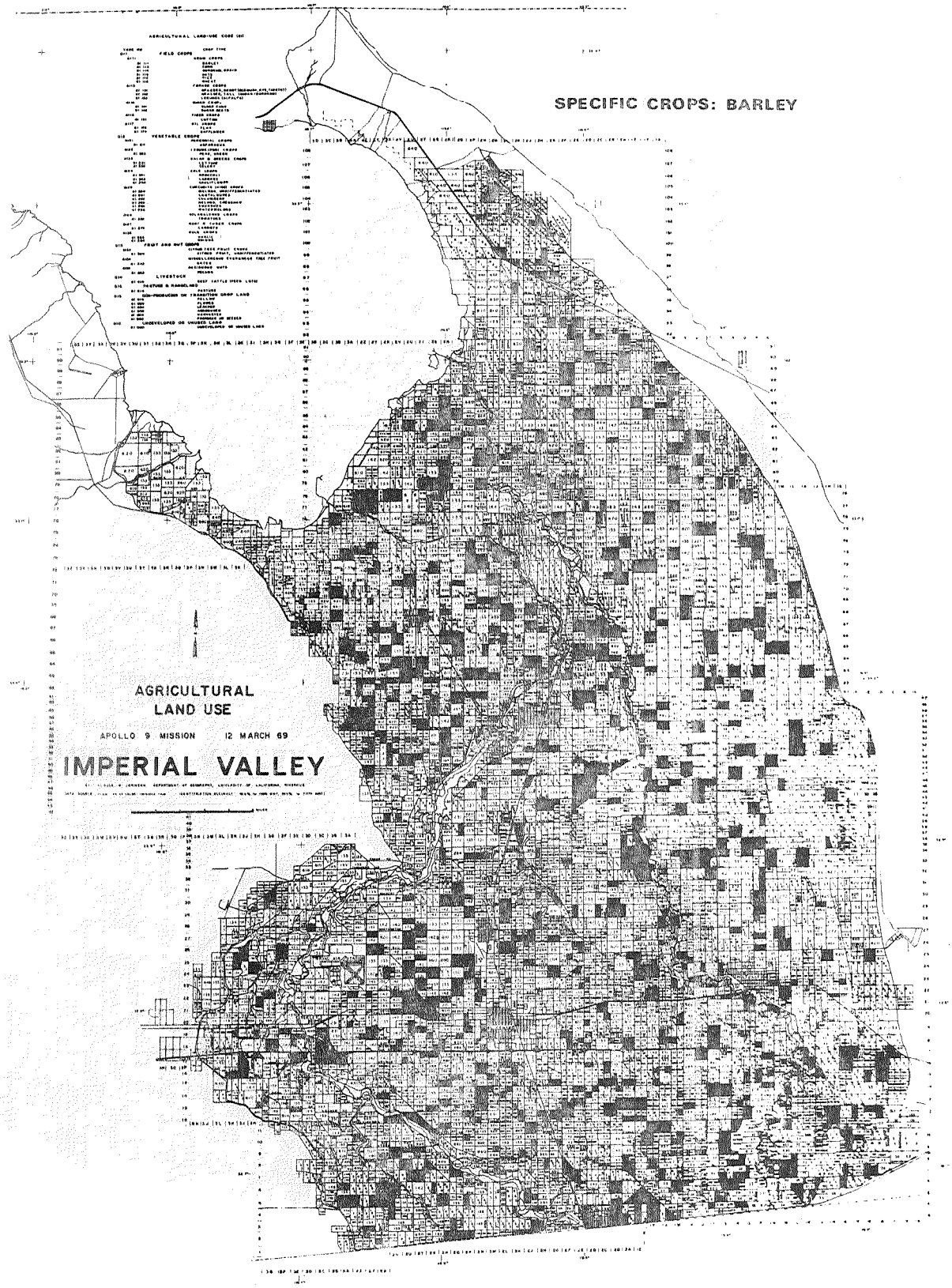
GROUND SURVEY ROUTES

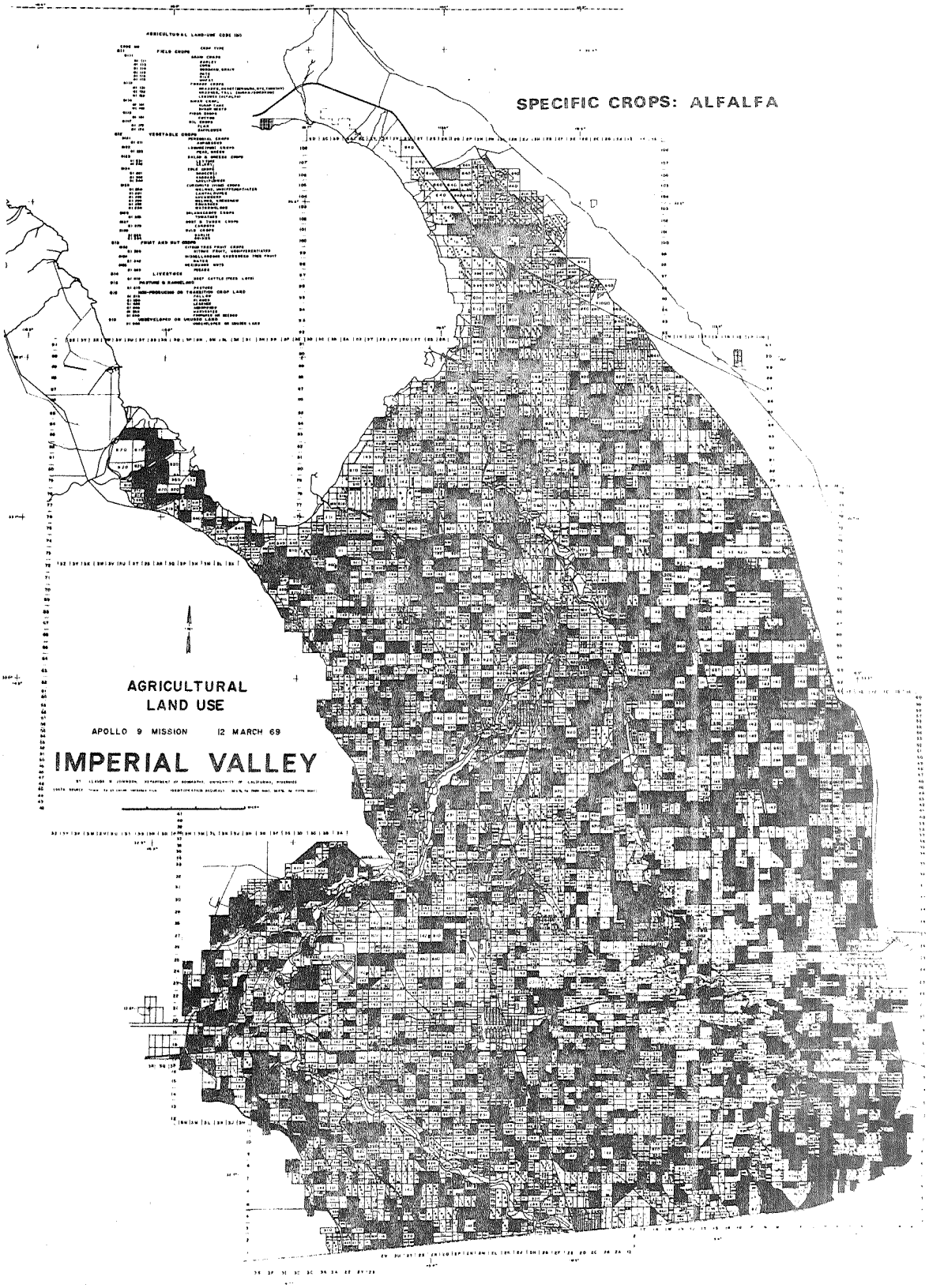


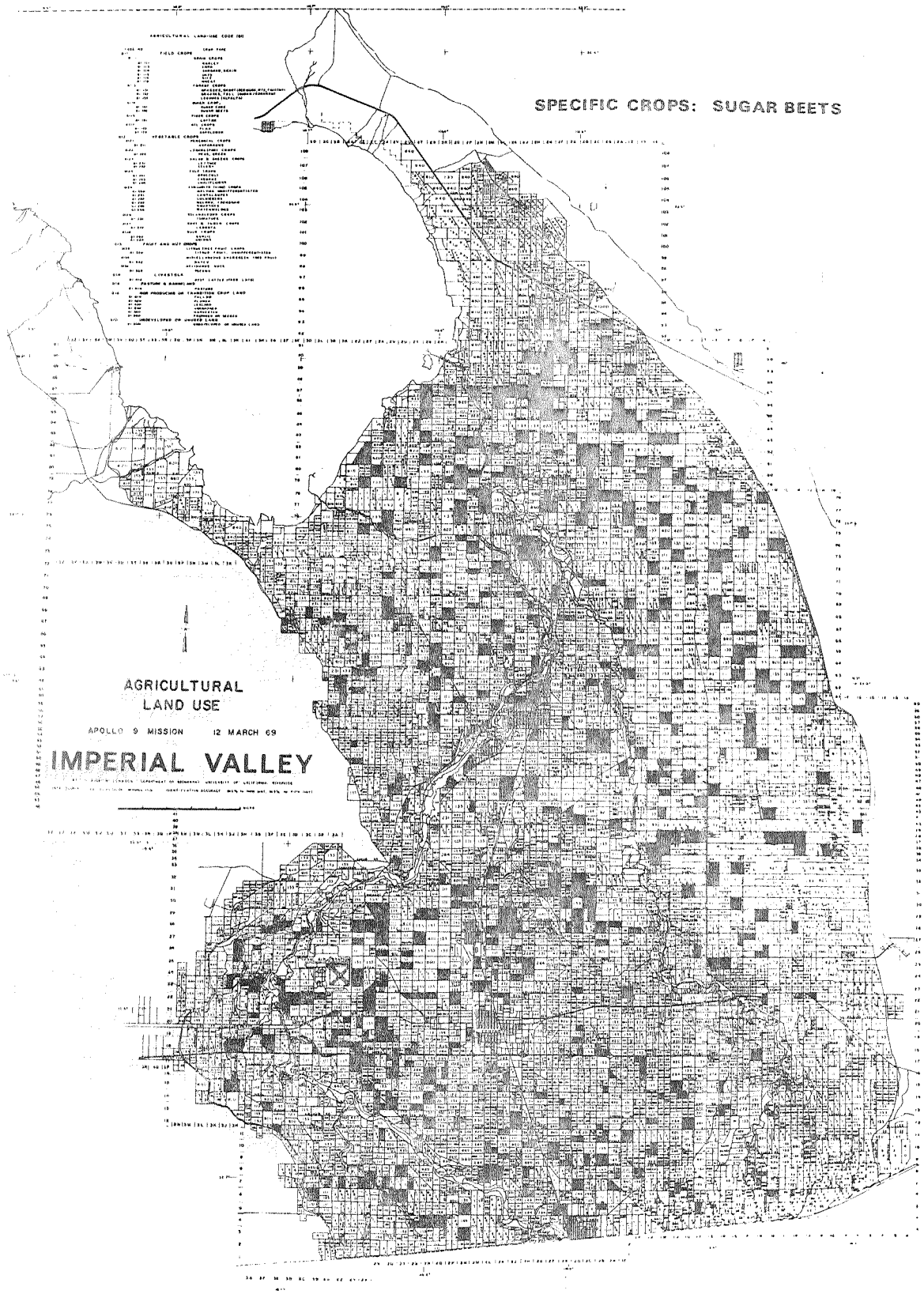
Appendix D Thematic Land Use Maps of the Imperial Valley from March 12, 1969 Apollo 9 Photography

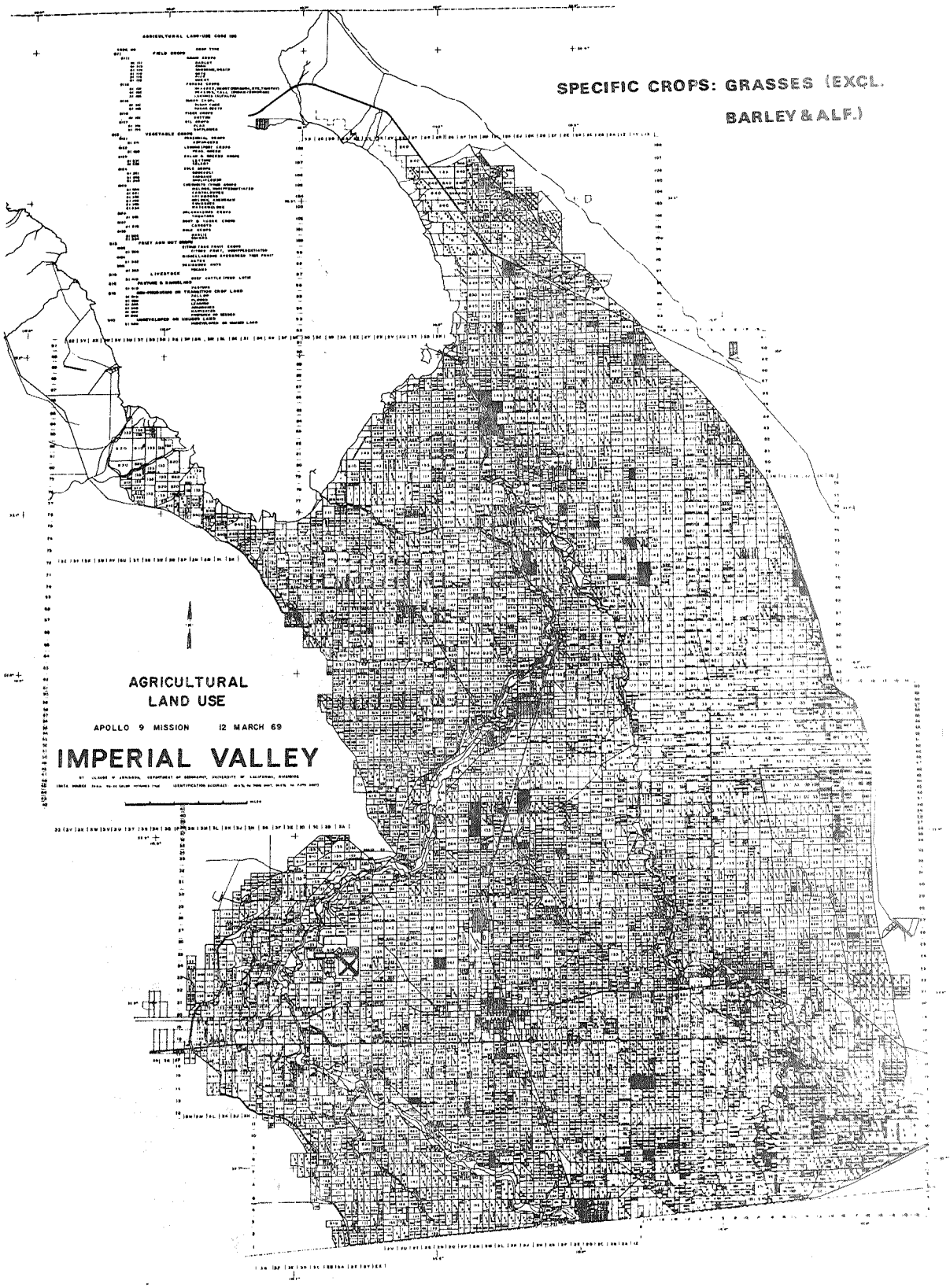
1. Barley, Alfalfa, and Sugar Beets 79
2. Barley 80
3. Alfalfa 81
4. Sugar Beets 82
5. Grasses (Exclusive of Barley and Alfalfa) 83
6. All Vegetables 84
7. Asparagus 85
8. Carrots 86
9. Lettuce 87
10. Onions 88
11. Plowed, Prepared or Seeded 89
12. Plowed 90
13. Prepared or Seeded 91
14. Fallow 92
15. Abandoned 93
16. Feed Lots 94

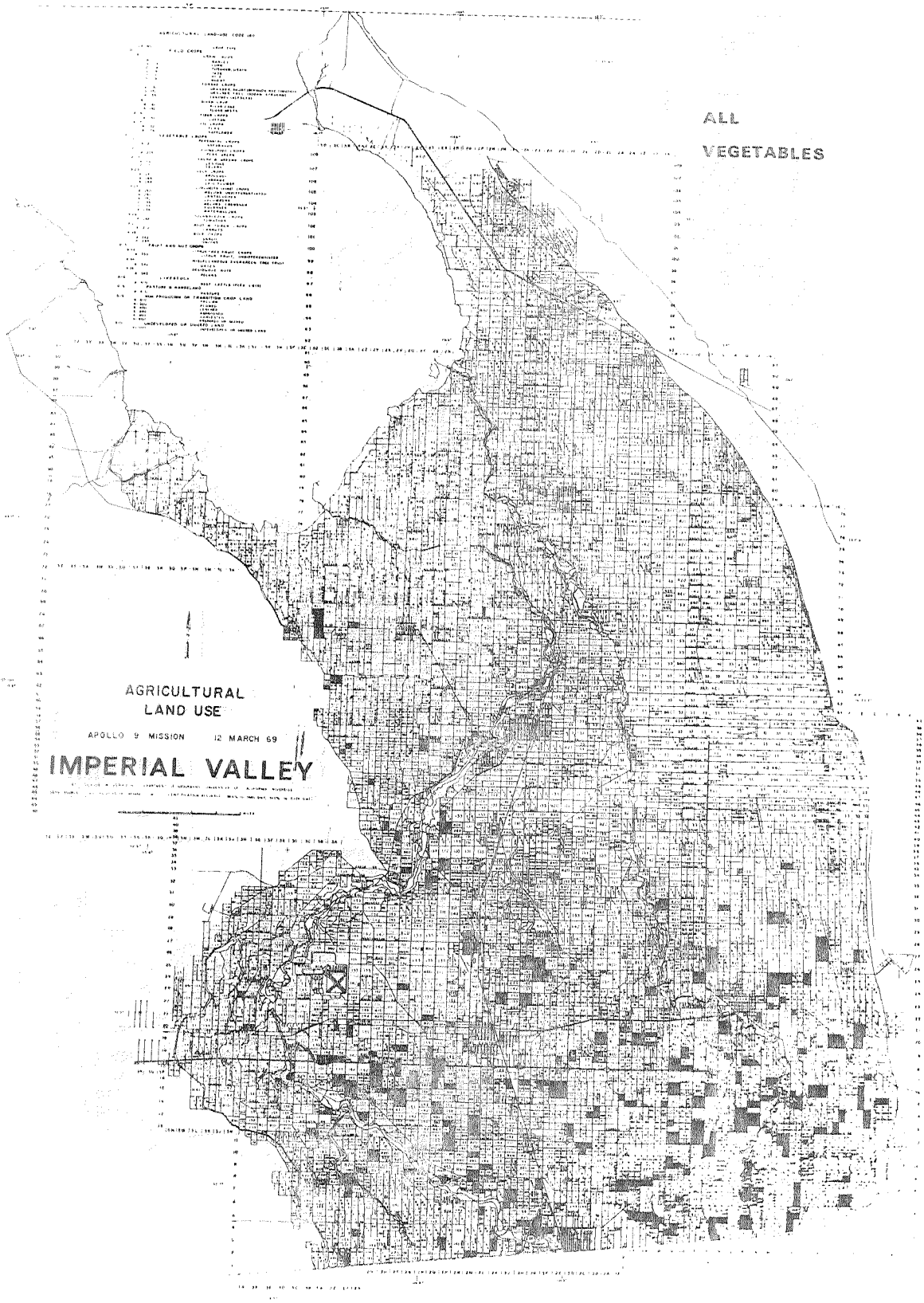

BARLEY
ALFALFA
SUGAR BEETS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

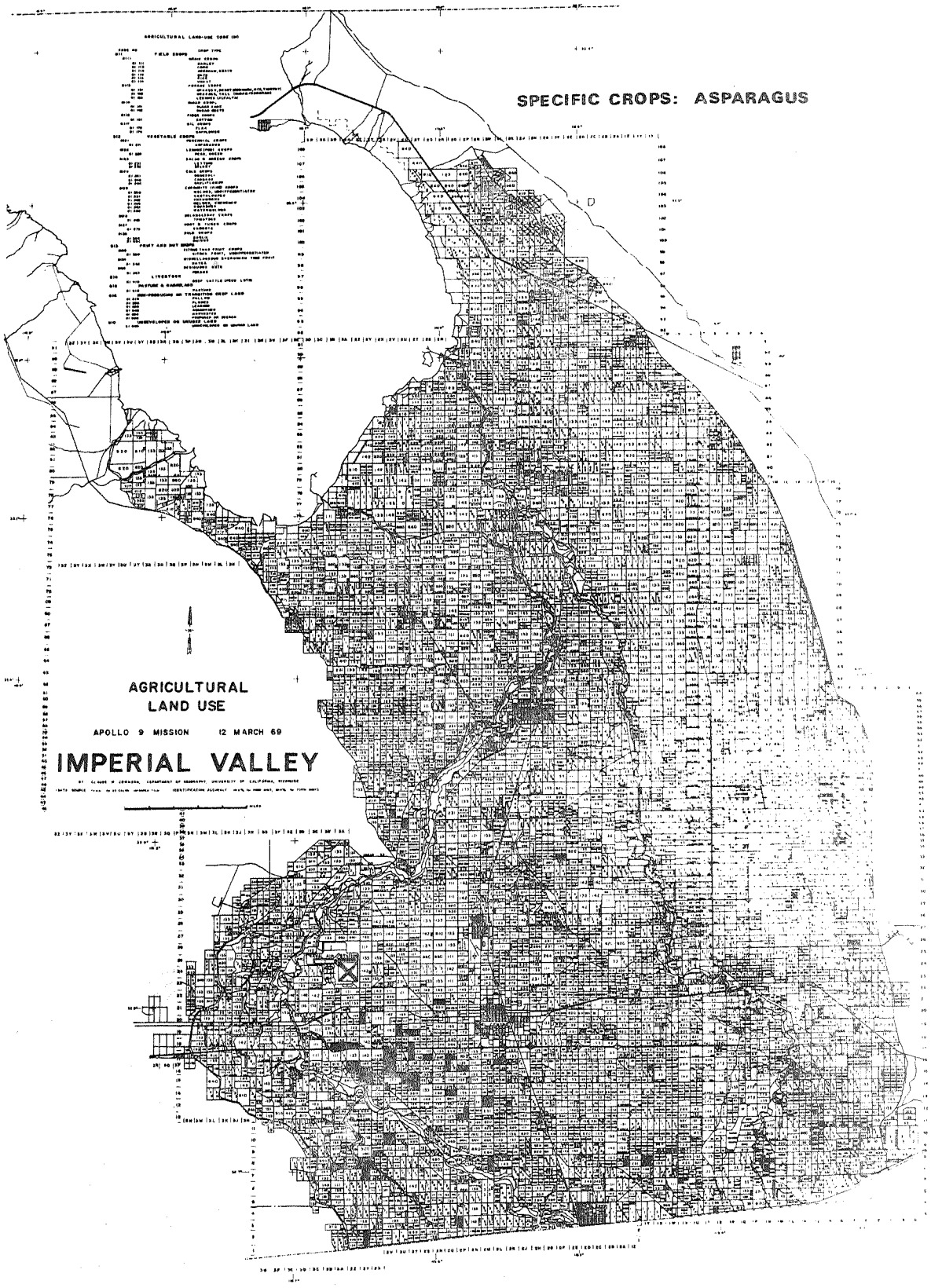

SPECIFIC CROPS: BARLEY
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

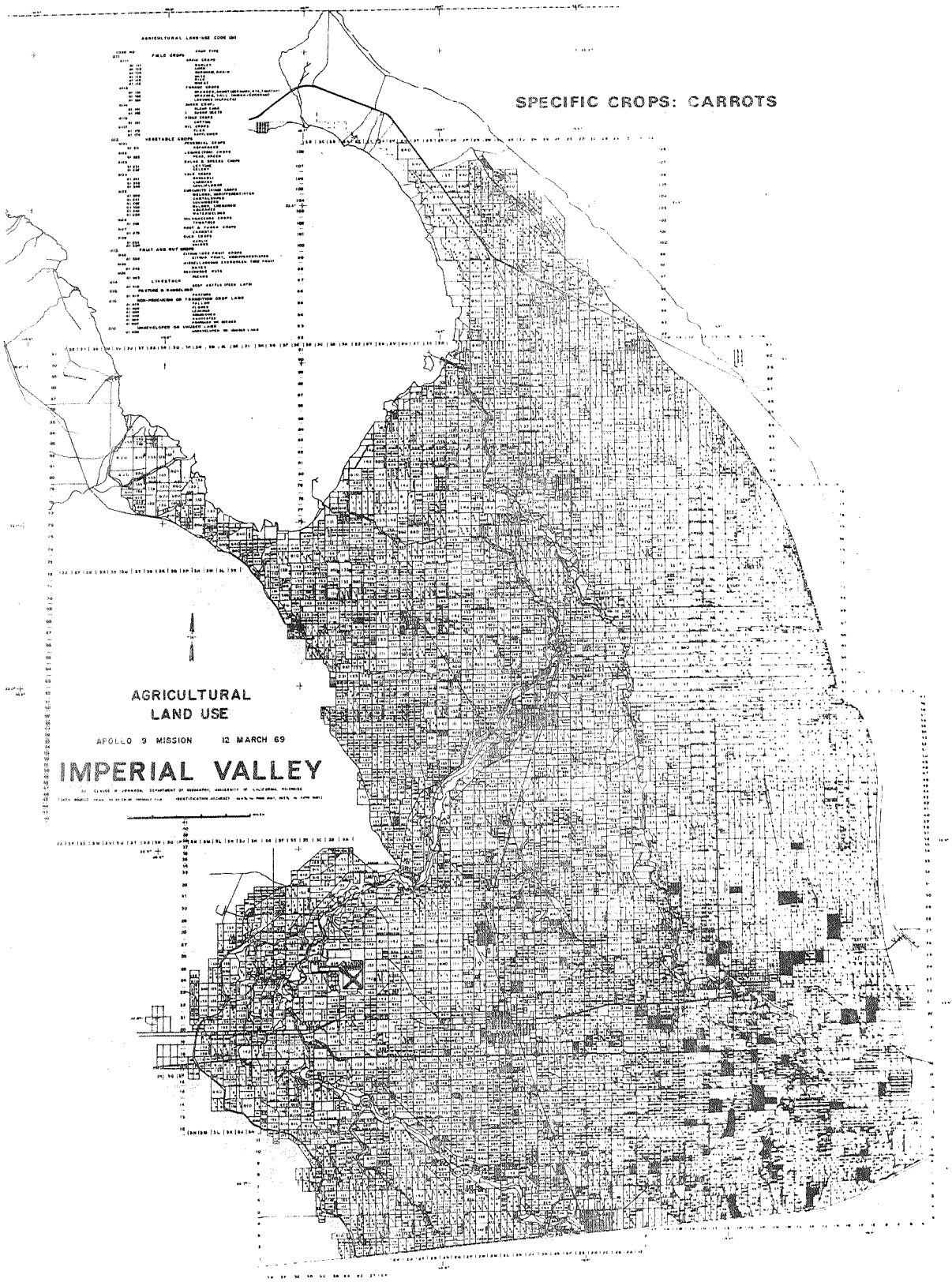

SPECIFIC CROPS: ALFALFA
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

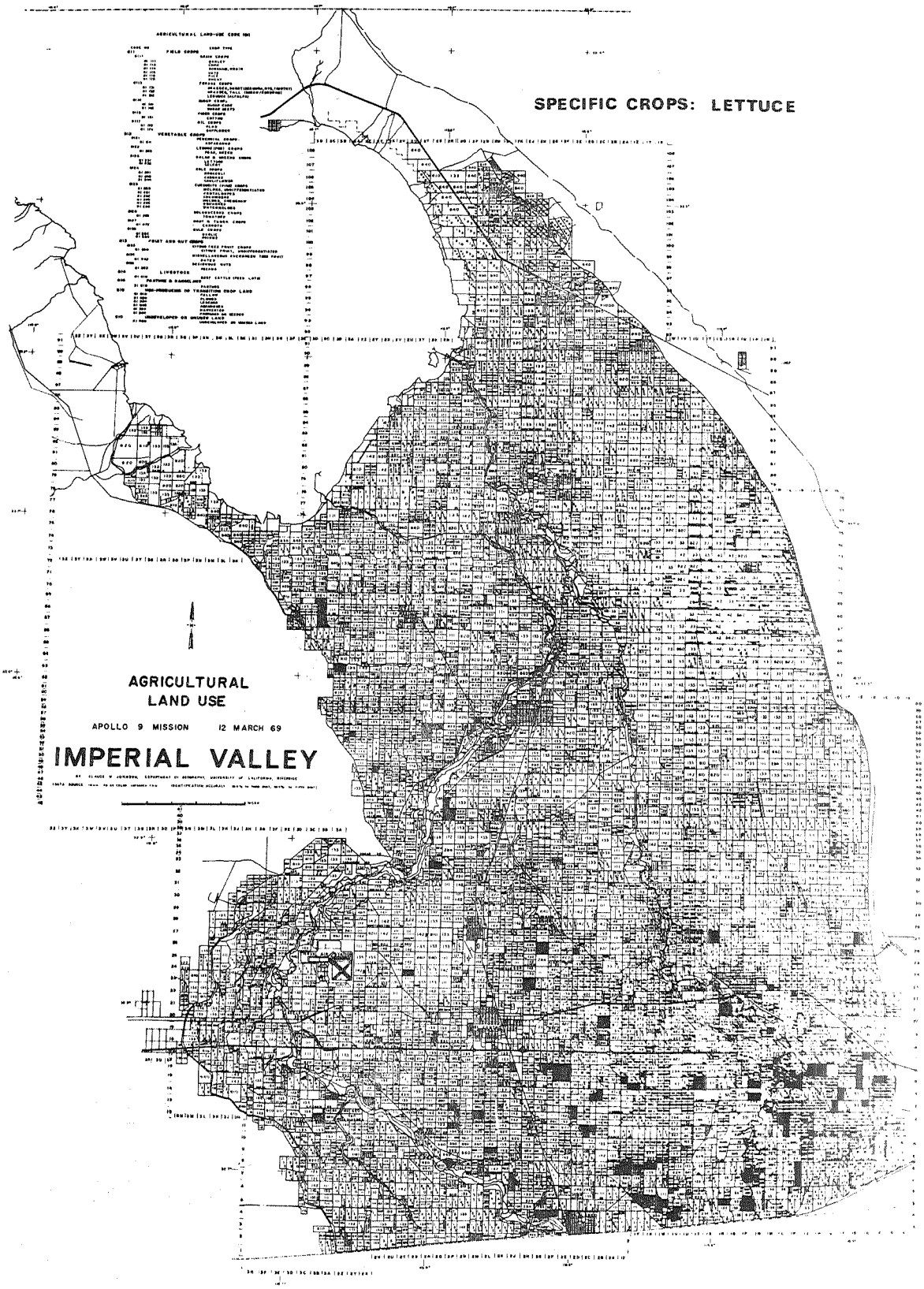

SPECIFIC CROPS: SUGAR BEETS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

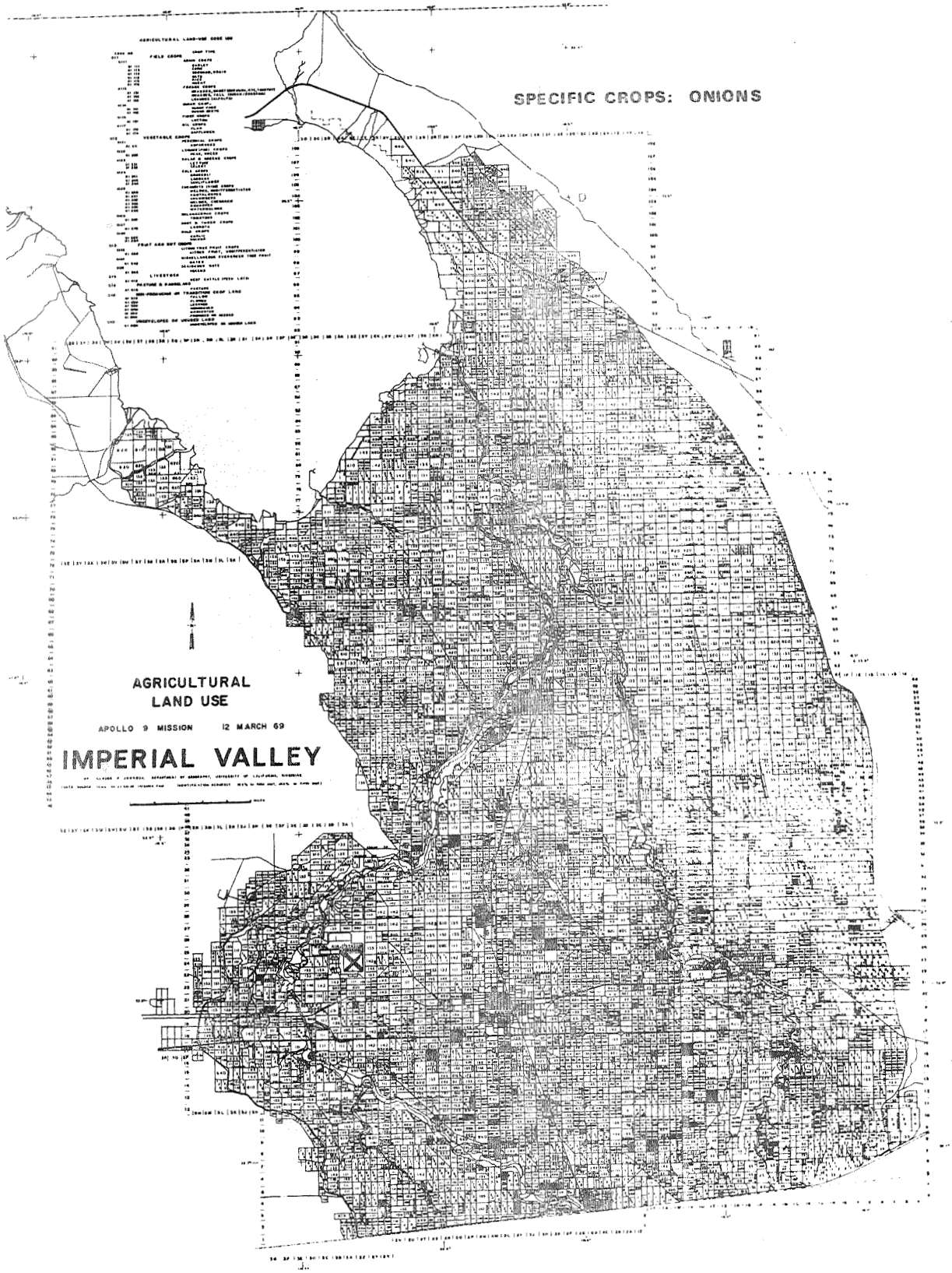

SPECIFIC CROPS: GRASSES (EXCL.
BARLEY & ALF.)
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

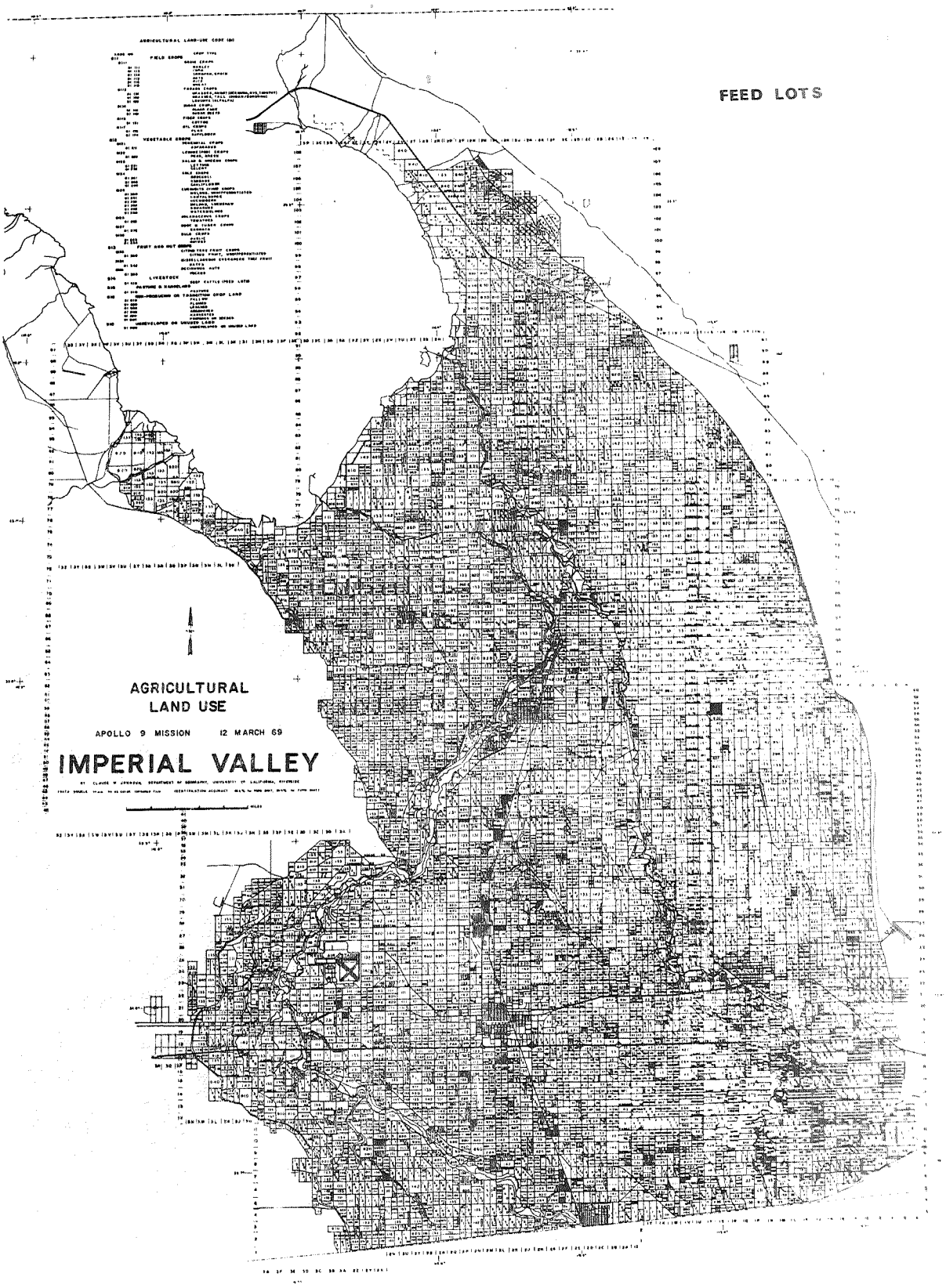

ALL
VEGETABLES
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

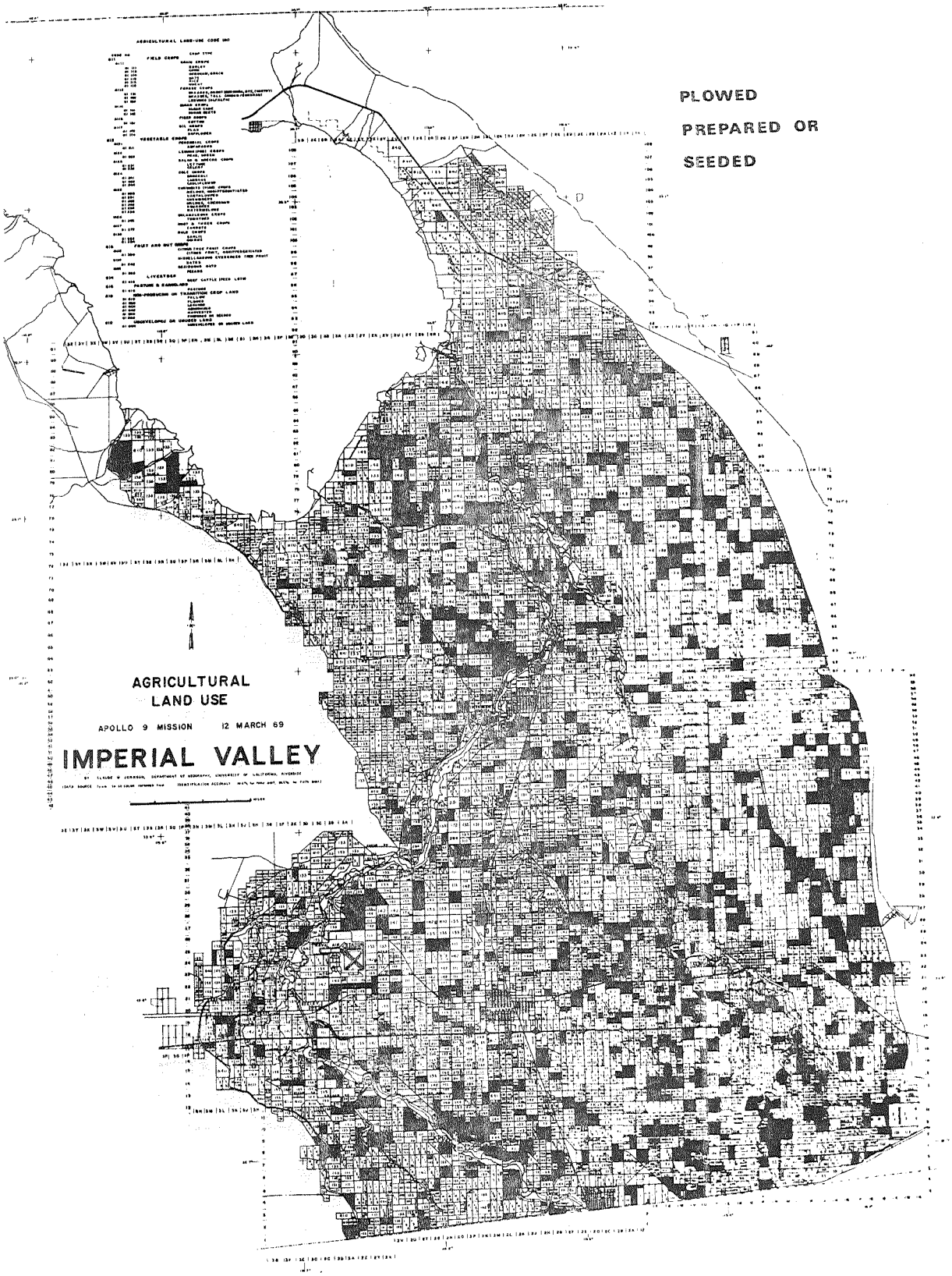

SPECIFIC CROPS: ASPARAGUS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

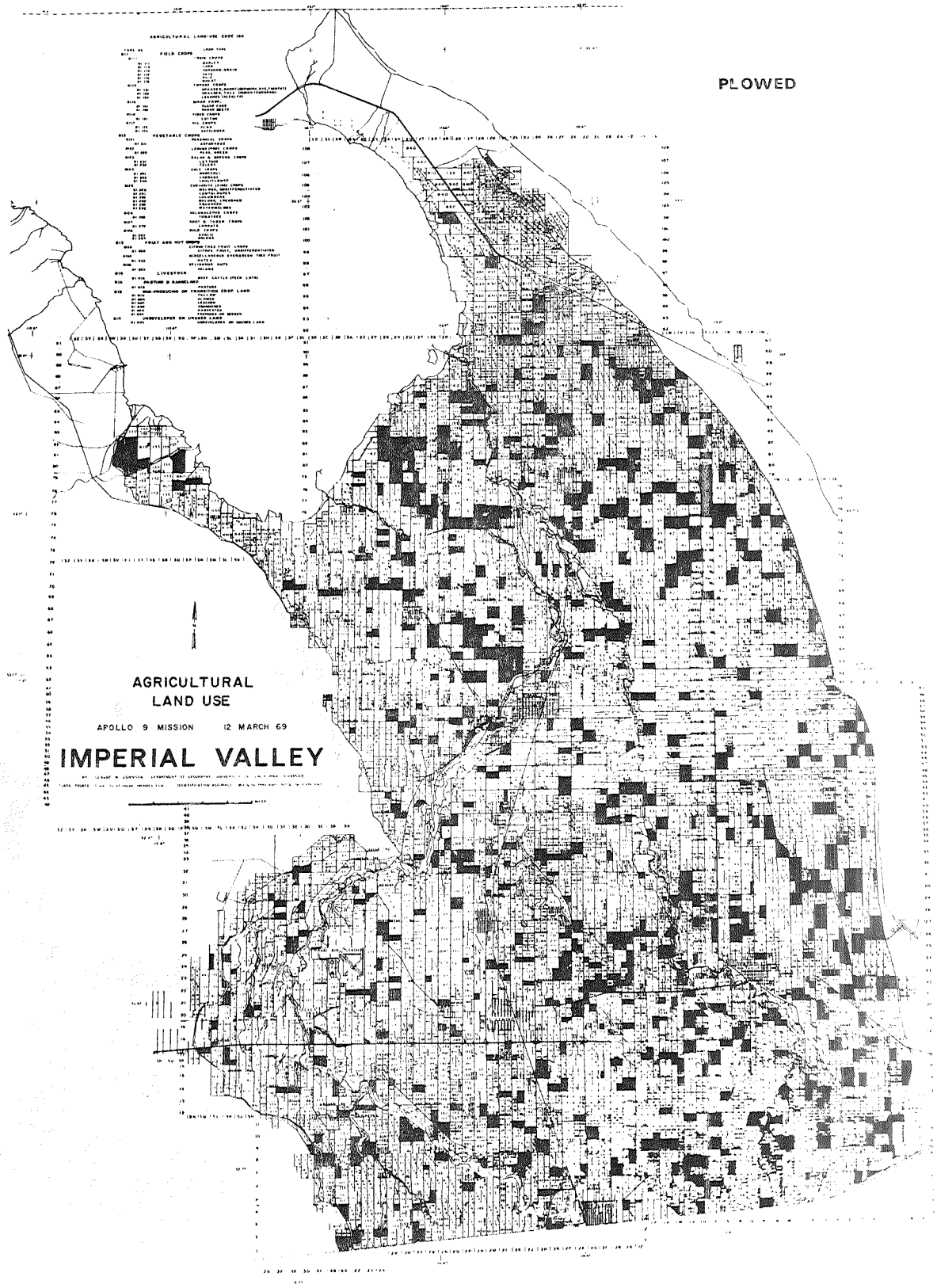

SPECIFIC CROPS: CARROTS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

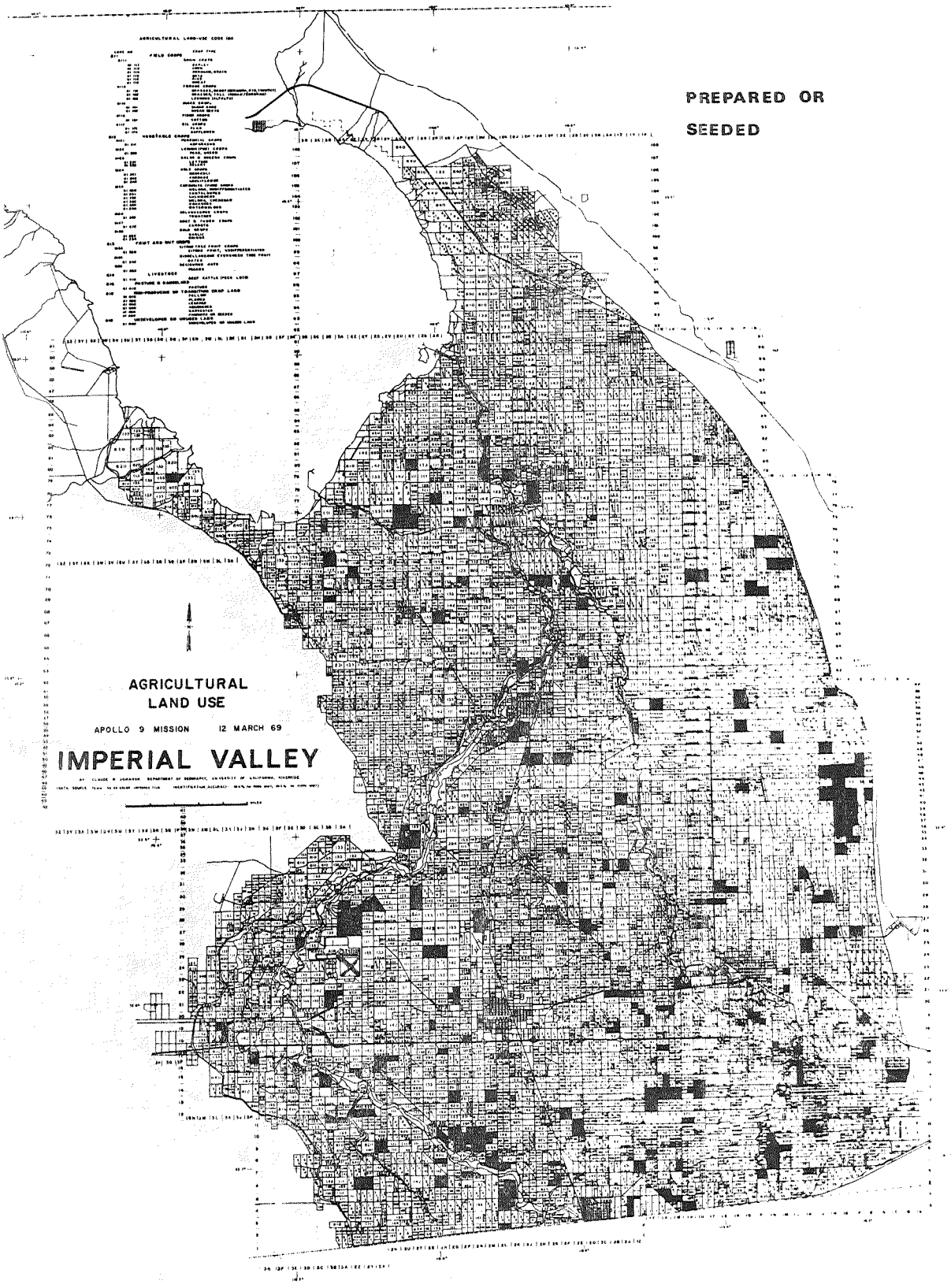

SPECIFIC CROPS: LETTUCE
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

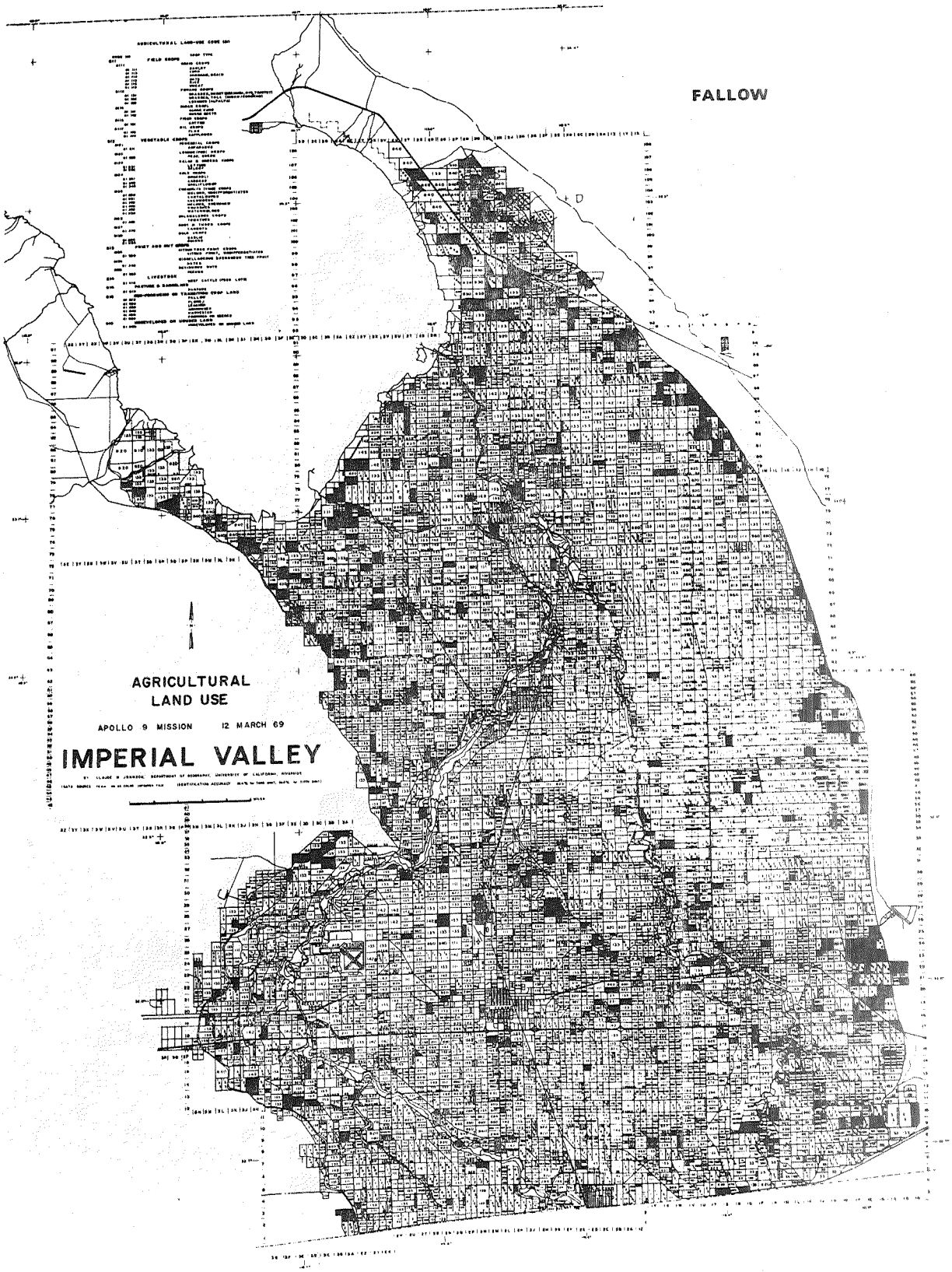

SPECIFIC CROPS: ONIONS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY


FEED LOTS
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY


PLOWED
PREPARED OR
SEEDED
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY


PLOWED
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY


PREPARED OR
SEEDED
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY


FALLOW
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

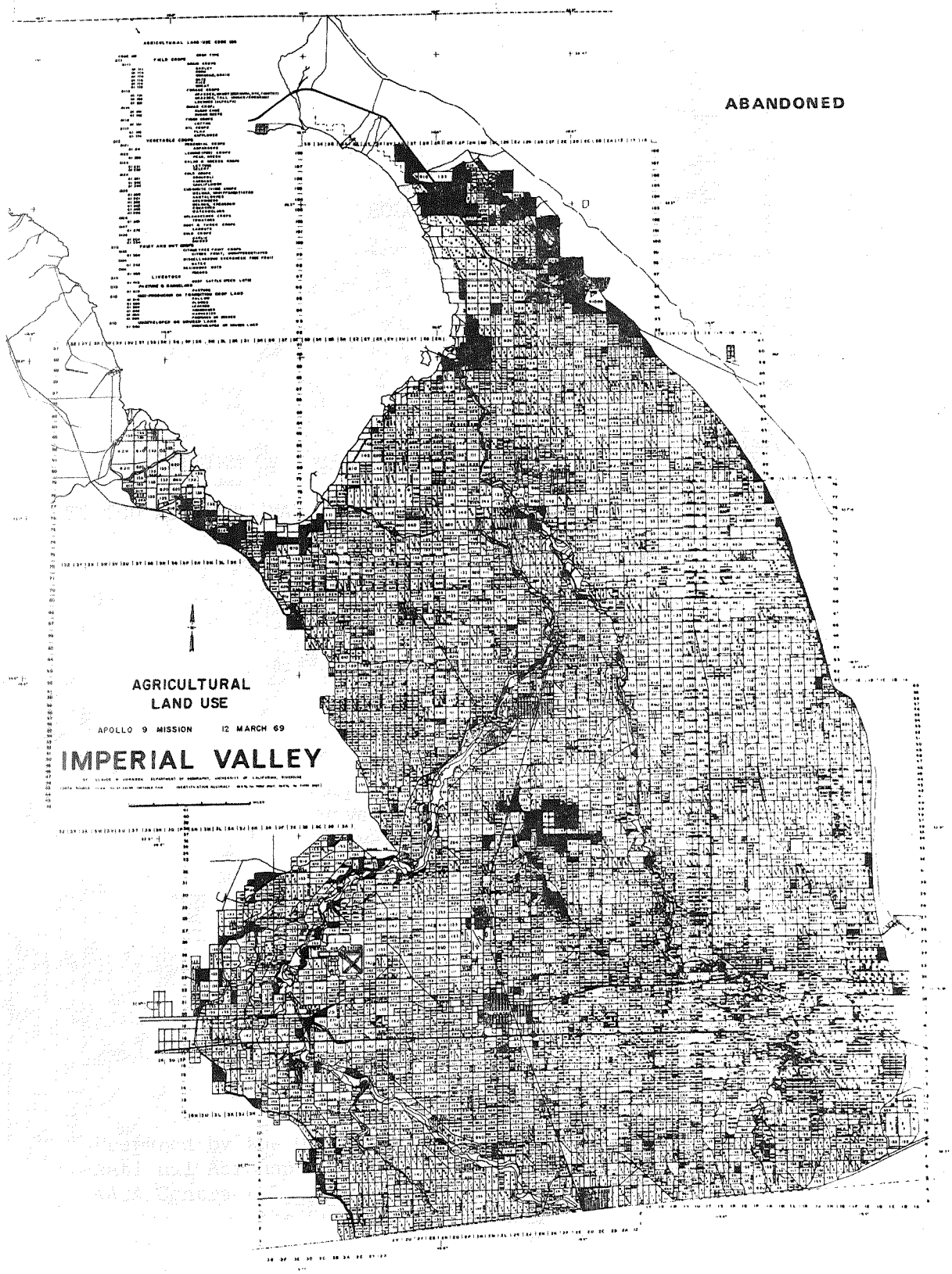

ABANDONED
AGRICULTURAL
LAND USE
APOLLO 9 MISSION 12 MARCH 69
IMPERIAL VALLEY

Plate 2 (Upper left)

Examples of varieties of crop colors on CIR imagery. (Original scale of 1:16,000 and resolution of 40 cm taken with filter combination of W 15 plus 8)B). The scale, resolution, and number of fields available on the same frame for comparison presents an excellent image for agricultural land use interpretation.

Identification Key to Plate 2.

111 Barley (or wheat)
133 Alfalfa (all stages of maturity)
151 Cotton
251 Cantaloupe
263 Tomatoes
410 Feed Lot (Beef cattle)
810 Fallow Land
820 Plowed Land
850 Harvest Land (Stubble)

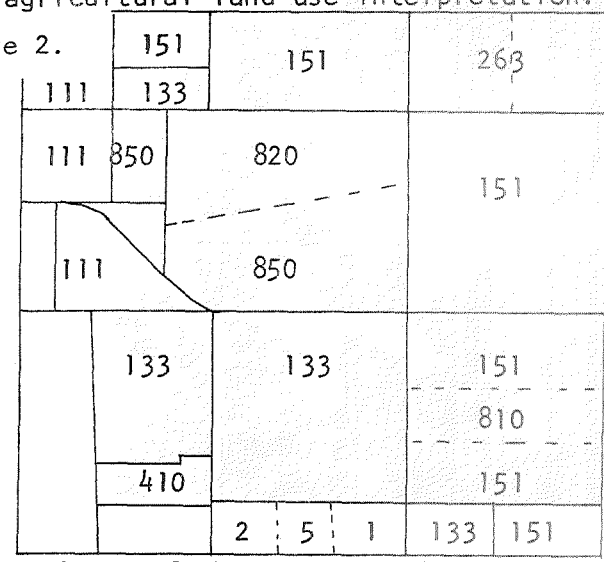


Plate 3 (Upper Right)

The 160 acre alfalfa crop in the center field of the picture, shown in three stages of cutting, is an example of CIR image color variation within the same field. The lower 3/5ths of the field has been raked into windrows for drying. The middle 3/10ths of the field has been cut and is waiting to be raked. The upper 1/10th is fully matured standing alfalfa.

Plate 4 (Lower left)

Examples of the same type crop (alfalfa) showing variations in color on CIR imagery due to different stages of growth.

Identification Key to Plate 4.

1 Cut and pastured Alfalfa field
2 Medium regrowth field of Alfalfa
3 Advanced regrowth field of Alfalfa
4 & 5 Mature Alfalfa field under irrigation
6 Fully matured Alfalfa field

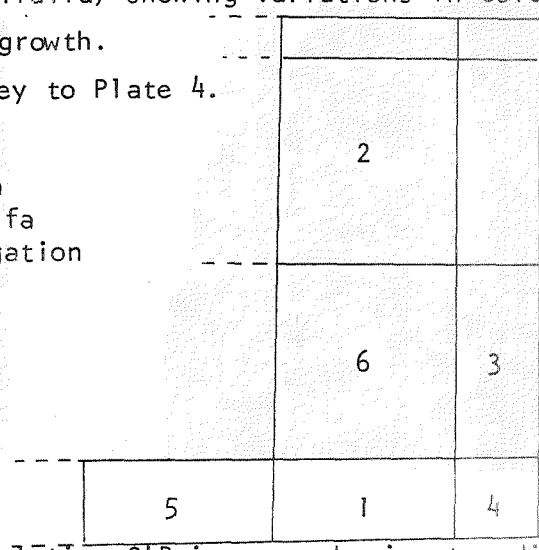
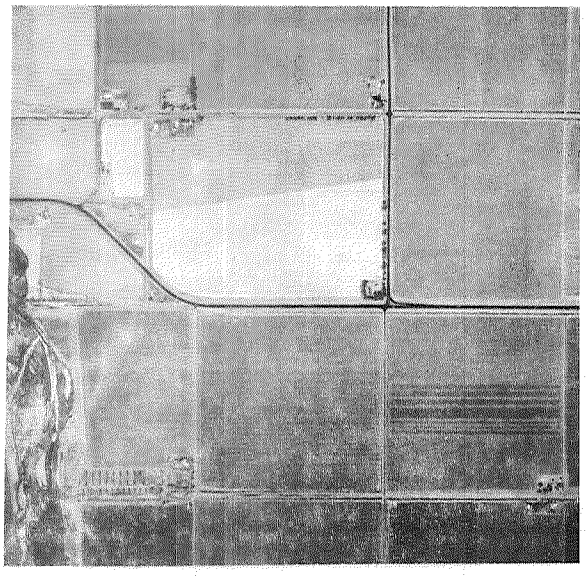
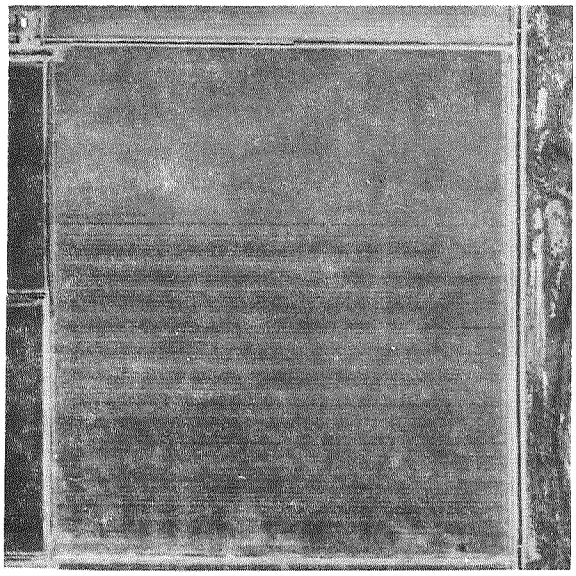
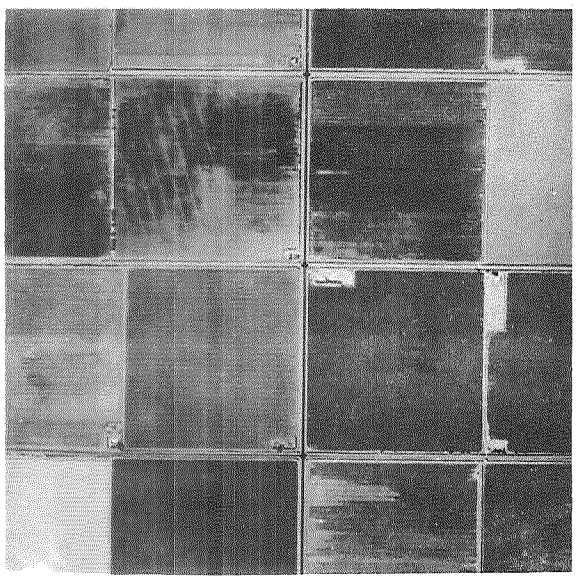


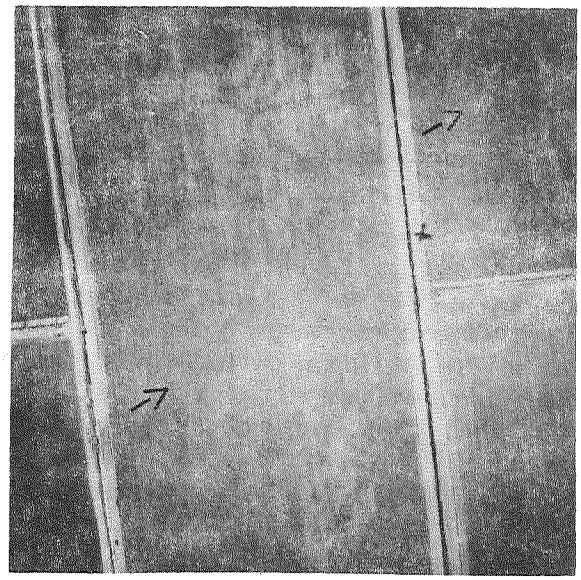
Plate 5 (Lower right)

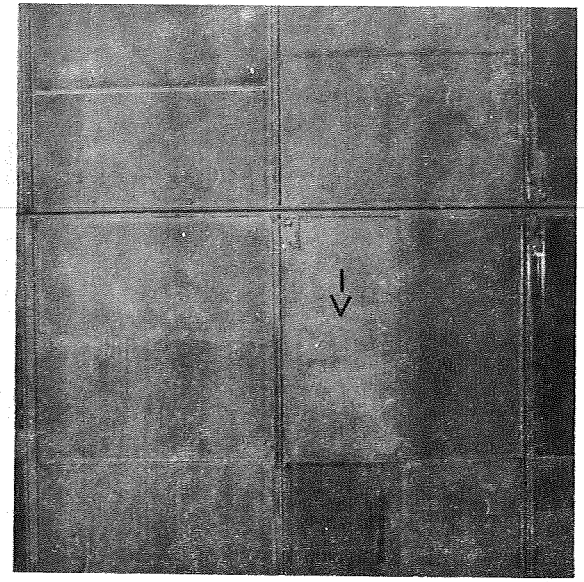
Example of low altitude, high resolution CIR imagery showing two different crop types reflecting the same false color. Center crop is mature sugar beets. Crop in upper right corner is young sorgham.

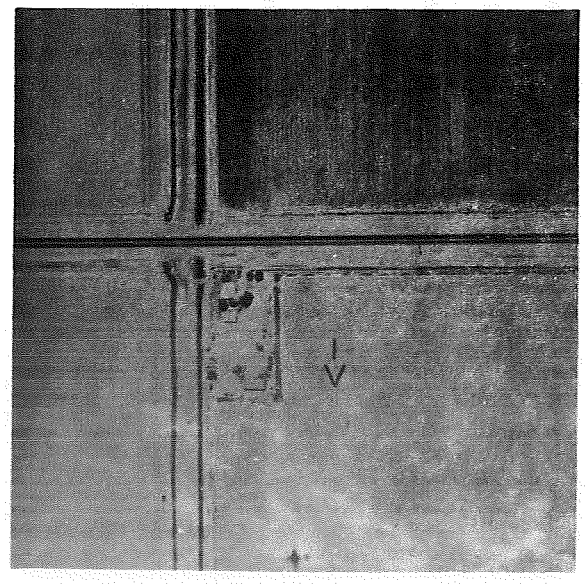












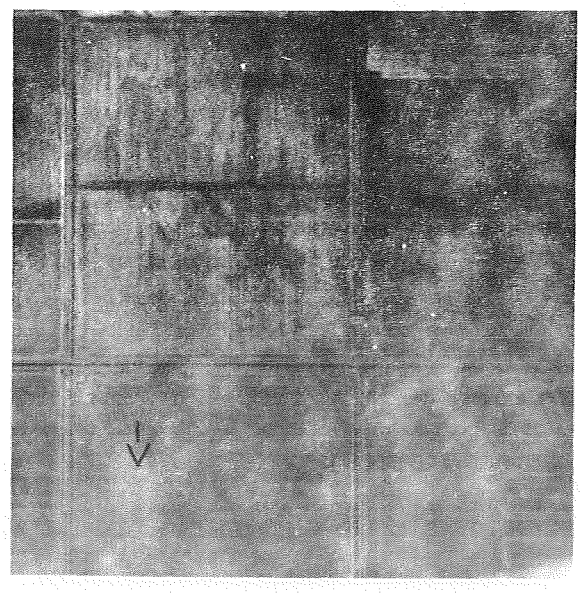


Plate 6 (Upper left)

Example of the effect of high resolution on CIR imagery. The false red color indicating the infrared reflectance of the vegetation (sugar beets) is separated from the brownish-yellow color of the dead leaves and soil background. Photo was taken at 2000 foot altitude with a 6 inch focal length RC-8 camera on May 21, 1968. (Ground resolution approximately 10 cm.)

Plate 7 (Upper left)

Same sugar beet field as in plate 6 showing how the false red vegetation color is integrated with the brownish-yellow background color on CIR imagery at medium resolution. Photo taken on May 24, 1968.

Plate 8 (Lower left)

The effect of time-lapse imagery is shown in this image of the same sugar beet field as in plates 6 and 7 taken at medium resolution 21 days later (June 11, 1968). The fallow brown soil color indicates the field has now been harvested. The faded or cloudy appearance of the print is due to smoke drifting under the flight path from the burning of barley stubble on the day of the mission.

Plate 9 (Lower right)

Ground CIR photo of a mature sugar beet field taken in May 1968 showing the reduced amount of infrared reflectance from the leaves of the plant. Many leaves which appear green in normal color show no IR reflectance in this picture and blend into the background color of the soil. The combined color of the dead leaves and the background soil will integrate with the IR reflectance to present an integrated color on medium resolution imagery which appears as a light pink compared to the vivid red that is seen on the ground photo.

N71-34375 NASA CR-121875

STANDARD TITLE PAGE FOR TECHNICAL REPORTS	1. Report No. USGS-DO-71-009	2. Gov't Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
A System of Regional Agricultural Land Use Mapping Tested Against Small-Scale Apollo 9 Color Infrared Photography of the Imperial Valley (California)

5. Report Date
November 1969

6. Performing Organization Code

7. Author(s) Claude W. Johnson, Leonard W. Bowden, and Robert W. Pease, Univ. of California, Riverside

8. Performing Organization Rept. No.
IR-USGS-183

9. Performing Organization Name and Address
U.S. Geological Survey
Geographical Applications Program
Washington, D.C. 20242

10. Project Task Work Unit No.
160-75-01-32-10

11. Contract Grant No.
NASA W-12570
USGS 14-08-00001-10674

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration
Washington, D.C. 20546

13. Type of Report & Period Covered
Final report

14. Sponsoring Agency Code

15. Supplementary Notes
Work performed by the University of California for the USGS Geographic Applications Program under USGS contract no. 14-08-00001-10674

16. Abstracts
Interpretation results of the small scale CIR photography of the Imperial Valley (California) taken on March 12, 1969 by the Apollo 9 earth orbiting satellite have shown that world wide agricultural land use mapping can be accomplished from satellite CIR imagery if sufficient a priori information is available for the region being mapped. Correlation of results with actual data is encouraging although the accuracy of identification of specific crops from the single image is poor. The poor results can be partly attributed to only one image taken during mid-season when the three major crops were reflecting approximately the same and their CIR image appears to indicate the same crop type. However, some incapacity can be attributed to lack of understanding of the subtle variations of visual and infrared color reflectance of vegetation and surrounding environment. Analysis of integrated color variations of the vegetation and background environment recorded on CIR imagery is discussed.

Problems associated with the color variations may be overcome by development of a semi-automatic processing system which considers individual field units or cells.

17. Key Words and Document Analysis. (a). Descriptors
Land use, Mapping, Spaceborne photography, Infrared photography

CASE FILE COPY

17b. Identifiers/Open-Ended Terms
Apollo 9

17c. COSATI Field/Group 8B, 8F, 14E

18. Distribution Statement
Unclassified - Unlimited

19. Security Class (This Report)	21. No. of Pages
UNCLASSIFIED	107
20. Security Class. (This Page)	22. Price
UNCLASSIFIED	$3.00

FORM NTIS-967(1-70)