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APPLICATION OF DIGITAL ANALYSIS OF MSS DATA TO AGRO-ENVIRONMENTAL STUDIES

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I. Columbia University, Geography Department, Remote Sensing Project.

Since June 1975, Columbia University, Department of Geography has been conducting research on various aspects of applying LANDSAT and other multispectral data to a broad range of topics related to agriculture, agricultural development, and the environment. The research is carried out in collaboration with the NASA/Goddard Institute for Space Studies (GISS) and is intended to support the Institute's program in Earth Resources.

The primary purpose of the research is to aid in identifying and developing a global agricultural monitoring system which would rely on satellite data collection systems as major data sources. This involves the study of three specific topics. 1) agricultural change, 2) traditional agricultural systems and 3) relationships between agriculture and the physical environment.

Primary data sources for these studies are simulated advanced multispectral sensors of various resolutions, 24-Channel multispectral scanner (MSS) data, LANDSATS 1 and 2, as well as other remote sensing data made available through the offices of GISS. MSS, LANDSAT, Skylab and aircraft spectrometer data are analyzed by means of GISS-developed software and computing facilities.

The faculty of the Department of Geography, Columbia works closely with GISS personnel as well as supervises the student research assistants who may undertake individual projects within the framework of this proposal.

Participating Columbia University faculty members from the Department of Geography are:

Professor Kempton E. Webb, Chairman

Professor Colin J. High

Dr. Jerry C. Coiner

In addition to the three principal investigators, the staff includes five funded graduate students, three part-time student technicians and four nonfunded graduate researchers.

The following reports and publications were presented or published by the staff during the reporting period.

1. "An Experimental Approach to a Settlement Pattern Study," Connie L. Gordon, a paper presented at the annual meeting of the American Anthropological Association, Washington, D.C., November, 1976.

2. "Photointerpretation Support of Spectroradiometer Agricultural Studies," Nancy M. Lytle, December, 1976.

3. Ground Truth Management System to Support Multispectral Scanner (MSS) Digital Analysis," Jerry C.

Coiner and Stephen G. Ungar, paper presented and published in the Proceedings of the American Society of Photogrammetry, 43rd Annual Meeting, February, 1977, pp 130-137.

Copies of these papers are included in Appendix A.

II. Experiments in Progress

A. Support to Thematic Mapper Design (J. Coiner)

A series of investigations are being conducted at the Goddard Institute for Space Studies to determine appropriate sensor parameters for the Thematic Mapper under development for LANDSAT D, which is scheduled to go into operation some time in the early 1980's. This scanner will provide data in up to 7 channels or bands at a higher resolution than the 4-Channel multispectral scanner (MSS) now on LANDSATS 1, 2 and C.

During the six months ending February 28, 1977 particular emphasis was placed on the role of sensor spatial resolution in classification accuracy. Classifications with different band configurations were undertaken to determine the impact of interband correlation and reflective configurations on crop identification and acreage assessment. In addition, initial studies on classification with thermal data were undertaken.

1. Ground Truth Support (S. Lytle)

To measure the accuracy with which the simulated TM sensor data could be classified for the crop classes known to exist in the test sites studied, it was necessary to develop files that could relate the ground identified thematic classes with the computer classification results.

Ground truth data files for North Dakota (8/15/75) were altered to improve continuity between the three overlapping flight lines. Consistency of land use coding was established on a field by field and pixel by pixel basis using four sources of data. They were as follows:

1) LACIE Intensive Study Site, 1/24,000 Land Use Map, June 1974 (with thematic overlays).
2) LACIE Ground Truth Inventory Form June 1975.
3) 1/20,000, RC-14, 9" color and CIR aerial photography flown August 15, 1975 (simultaneously acquired with 24-Channel MSS data).
4) Original gray scale digitized computer printout with field number overlay (created at GISS).

The LACIE Ground Truth Inventory Form and the aerial photography were primary sources for identification of crop type categories, while the 1/24,000 land use map and gray scale printout were used to establish spatial congruence between the ground truth and the sensor data.

Correction overlays were constructed for each flight line delimiting the pixels which needed to be recoded. The x-y coordinate of each pixel was then used as input for a series of computer runs which made the specified corrections on the existing ground truth files. The next step was to view each altered flight line side by side with the other two flight lines on Ramtek color video display system. This technique allowed for checking results to insure that consistency within each flight line and between the flight lines had been achieved. The Ramtek display system, by comparing the original and the altered gorund truth files, also assured that areas were correctly coded.

2. Classification Studies (H. Wilson)

The purpose of these investigations is to assess the effectiveness of alternative combinations of channels and resolutions for agricultural crop analysis. The Thematic Mapper instrument is simulated using selected channels from data acquired by a 24-Channel multispectral scanner flown over selected Large Area Crop Inventory Experiment (LACIE) test sites in Williams County, North Dakota and Finney County, Kansas during the summer of 1975. The data were subsequently degraded from an acquisition resolution of approximately 6 meters to both 30 and 60 meter resolutions.* (Preparation of ground truth used with these data is described in the previous section of this report.)

To date, minor modifications have been made to the North Dakota (Aug. 15, 1975) classification results summarized in Table 2, p. 14 of the Semi-Annual Report for the period March-September, 1976. These modifications result from the

*See "Final Report," NASA Contract NAS9-14016, the Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, 1976, for description of the data preparation for the Thematic Mapper simulation.

ground truth corrections described in the previous section of this report. The modified classification results are shown in Table 1 of this report.

Of particular interest are the studies designed to test the impact on classification accuracy of the addition of the thermal band (band 7, 10.10-12.00/micrometers) at both 30 and 120m resolutions to the 30 meter reflective bands (bands 1, 3, 4, 5, and 6, in the range of from 0.47 to 1.62 micrometers).

These studies were done on the North Dakota August data. The procedure for this set of studies was as follows:

1. Band 7, at both 30 and 120 meter resolution was added to the full set of reflective bands and classification was performed using this band configuration (Configuration III).

2. In order to determine if band 7 would have any significant impact when added to a smaller set of reflective bands, each configuration of the 4 reflective bands (1, 3, 4+5, 6), taken 3 bands at a time, was tested on the training areas. The 3-band reflective configuration that performed most poorly in terms of total classification accuracy was selected as the one to which the thermal band would be added. The same procedure was repeated in order to select the "worst" 2-band con-

TABLE 1

SUMMARY STATISTICS

CLASSIFICATION STUDIES, AS OF MARCH 1, 1977

NORTH DAKOTA, AUGUST 15, 1975

RESOLUTION	30M REFLECTIVE/120M THERMAL							60M REFLECTIVE 120M THERMAL			30M REFLECTIVE 30M THERMAL		
CONFIGURATION	I	II	III	IIID	IIIE	IVA	IVA7	I	II	III	III	IIIE	IVA7
BANDS	1,3,4,5,6	1,3,4+5,6	1,3,4+5,6,7	1,3,6	1,3,6,7	1,3	1,3,7	1,3,4,5,6	1,3,4+5,6	1,3,4+5,6,7	1,3,4+5,6,7	1,3,6,7	1,3,7
DATA SET	ACCURACY OF CROP IDENTIFICATION (PERCENT)												
TRAINING AREAS	84	83	85	74	76	62	62	79	79	79	86	81	66
FLIGHT LINE 1	74	74	73	67	65	58	55	70	70	66	75	69	58
FLIGHT LINE 2	73	72	68	60	53	50	46	70	70	64			
FLIGHT LINE 3	66	65	61	53	48	46	44	60	60	54			
DATA SET	ACCUARCY OF CROP ACREAGE ESTIMATION (PERCENT)												
TRAINING AREAS	88	86	86	75	78	60	60	86	84	82	86	79	61
FLIGHT LINE 1	79	77	76	63	58	46	42	78	78	67	78	63	43
FLIGHT LINE 2	74	71	68	48	32	30	19	77	76	63			
FLIGHT LINE 3	62	62	48	35	29	25	27	57	54	32			

figuration from among the previously selected 3 bands and the "worst" single-band configuration from among these 2 bands.

3. The selected 3-band and 2-band reflective configurations (IIID and IVA, respectively) as well as the associated thermal configurations (IIIE and IVA7, respectively) were applied to the available test sites. (3 flight lines for the 120 meter thermal resolution data and 1 flight line for the 30 meter thermal resolution data).

The results shown in Table 1 for flight line 1 are plotted in Figure 1. (Only data for flight line 1 were available for both 120 meter and 30 meter thermal resolution.) Additional work to test the impact of the thermal band when combined with a single reflective band is ongoing.

The most extensive classification studies have been conducted on the North Dakota data from Aug. 1975, as these data are the best quality from among the available data. Classification on the June North Dakota data and the July Kansas data is limited to assessing the differences in classification accuracy between 30 and 60 meter resolutions for the full reflective band configuration (Configuration I). Summary classification results for these data are shown in Table 2.

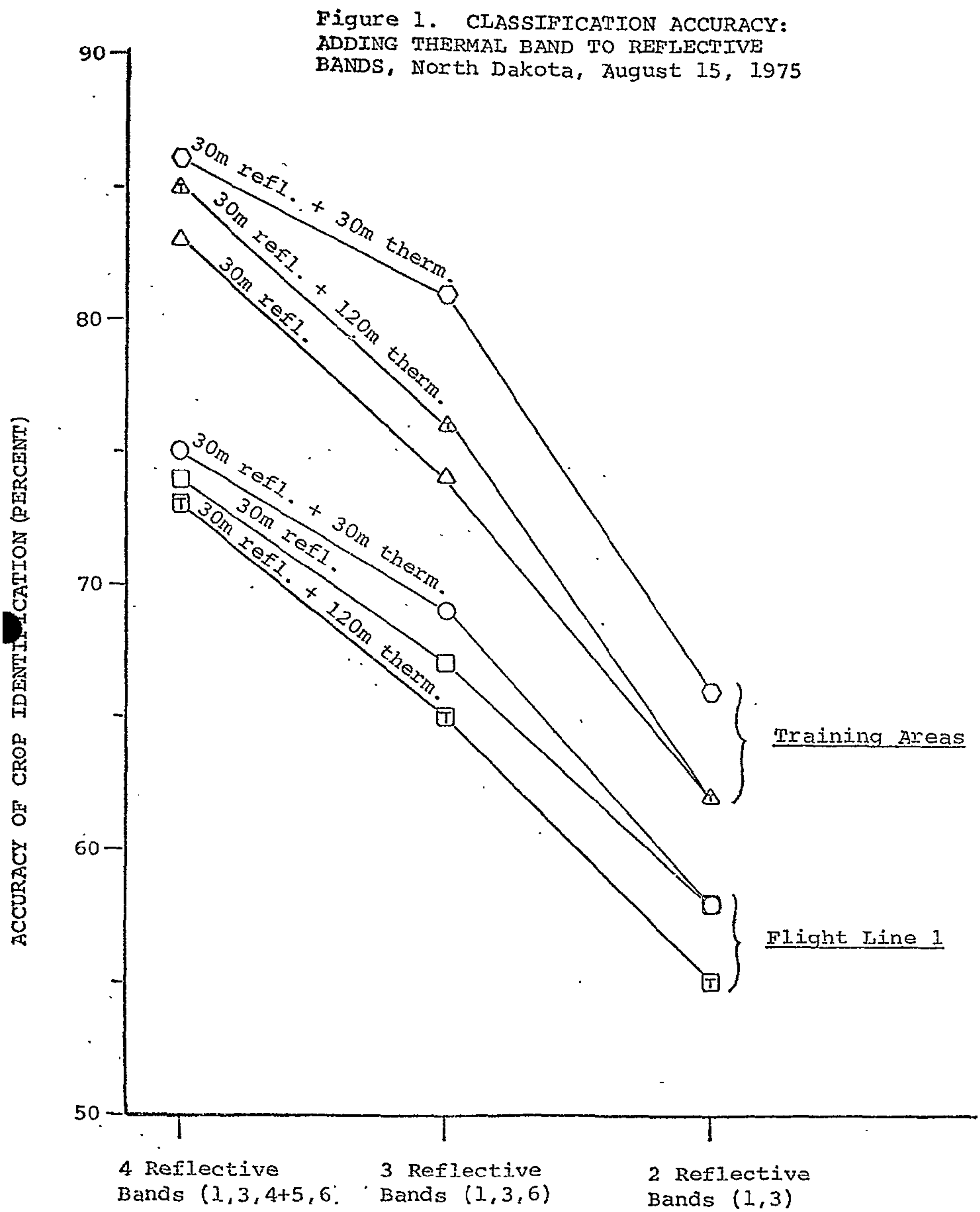


Figure 1. CLASSIFICATION ACCURACY:
ADDING THERMAL BAND TO REFLECTIVE
BANDS, North Dakota, August 15, 1975
90
80
70
60
50
ACCURACY OF CROP IDENTIFICATION (PERCENT)
30m refl. + 30m therm.
30m refl. + 120m therm.
30m refl.
30m refl. + 30m therm.
30m refl.
30m refl. + 120m therm.
Training Areas
Flight Line 1
4 Reflective
Bands (1,3,4+5,6
3 Reflective
Bands (1,3,6)
2 Reflective
Bands (1,3)

TABLE 2

SUMMARY STATISTICS

CLASSIFICATION STUDIES, AS OF MARCH 1, 1972

	NORTH DAKOTA, JUNE 22, 1975		KANSAS, JULY 6, 1975	
RESOLUTION	30 M REFLECTIVE	60 M REFLECTIVE	30 M REFLECTIVE	60 M REFLECTIVE
CONFIGURATION	I			
BANDS	1, 3, 4, 5, 6			
DATA SET	ACCURACY OF CROP IDENTIFICATION (PERCENT)			
TRAINING AREA (S)	74	72	82	78
FLIGHT LINE 1	59	55		
FLIGHT LINE 3	56	51	54	58
DATA SET	ACCURACY OF CROP ACREAGE ESTIMATION (PERCENT)			
TRAINING AREA (S)	84	79	81	77
FLIGHT LINE 1	70	67		
FLIGHT LINE 3	60	56	38	45

B. Support to Airborne Spectroradiometer Studies. (N. Lytle)

GISS/Columbia has developed a high resolution airborne spectroradiometer. This instrument acquires line trace spectra over sequential ground spots approximately 60 x 60 feet. To aid in interpreting these spectra and relating them to specific ground locations, a 35 mm photogrpah is acquired with every tenth image. Images acquired by the system over Imperial Valley, California were interpreted by Columbia geographers to support the production of the GISS Crop Spectra Atlas now being prepared. Document 2 of the Appendix is the photo interpretation report provided to GISS.

C. Agricultural Change Studies

1. Monitoring Agricultural Transition in Southern New Jersey. (P. Neary)

Agriculture is one of this nation's most important industries. It is also the prime activity through which man modifies the natural ecosystems of the earth. It is therefore of importance that the decision makers in both the business and government sectors have an accurate picture of the state of agricultural production from season to season and of the long-range trends which different agricultural regions are following. This research is exploring the possibilities of monitoring agricultural change with LANDSAT data. One such attempt using data from southern New Jersey is described below.

The ability to detect and measure agricultural change allows one to assess the impact of new land uses on the social and business community and on the environment of a particular region. There are a number of reasons for investigating the type and amount of agricultural change which may be occurring. First, there are the economic considerations. Local agribusiness must identify regional trends in order to anticipate future demands of specialized services. A fertilizer manufacturer must know what crops are gaining in importance so that he can plan the production, distribution, and storage of his product. A dealer in farm machinery would be interested in agricultural trends to aid in planning for future machine inventory and maintenance demands. Builders of storage facilities might watch regions in the process of converting their cropping systems in order to be able to provide them with necessary warehousing. Commodity brokers, wholesalers, and retailers have an interest in how agricultural change will affect prices. Local governments use agricultural statistics to establish assessment values and tax rates.

Secondly, environmental conditions are affected by agricultural change. Different cropping systems require different types of fertilizer, herbicide, and pesticide which affect the environment when used and perhaps for a long time afterward. Irrigation practices can affect groundwater supplies or alter flow in streams. In addition, certain crops can encourage or discourage particular organisms from entering a particular environment.

Since agriculture represents a renewable resource whose cycle of renewability can be as short as two months, monitoring the resource is an onerous and expensive task. Traditional methods of data collection such as ground surveys and aerial photographs are more appropriate for analysis of static or relatively slowly-changing phenomena - for example, nonrenewable resources or geologic features. "Monitoring" has been described as the process of "obtaining a new inventory periodically."[1] LANDSATS 1 and 2, earth resources satellites maintained by the National Aeronautics and Space Administration, offer a means to collect data periodically at little expense to the user. The frequency of coverage makes LANDSAT a potentially powerful instrument for monitoring a very changeable resource.

The methodology proposed is being tested on an area in southern New Jersey, where it is known that a change in land use is most likely occurring due to the loss of a specific market. Should the monitoring of agricultural transition in New Jersey prove feasible, it may be extended to other agricultural regions which are currently undergoing rapid change.

[1]American Society of Photogrammetry, Manual of Remote Sensing (Falls Church, Virginia: American Society of Photogrammetry, 1975), p. 5.

Location and General Characteristics

For this experiment, we chose an area in southern New Jersey which is known to be under considerable pressure to adjust to new agricultural circumstances. Figure 2 shows the approximate location of the study area, which is about twenty-five miles south of Philadelphia, Pennsylvania, and ten miles west of Vineland, New Jersey. Figure 3 shows more specifically the area which is being analyzed.

This region lies in both Salem and Cumberland counties, within the Upper Pittsgrove and Alloway Townships in Salem County and the Upper Deerfield Township in Cumberland County. Upper Pittsgrove and Alloway are in the central portion of Salem County. The landscape is gently rolling, underlain by geologic formations of loosely consolidated sedimentary deposits. Soils in the parts of these townships which are in the test area belong to a soil association that is silty, well-drained to poorly drained, nearly level to gently sloping.[1]

In 1953 this part of Salem County was characterized by "dairy-cash crop and corporation vegetable farming on heavy textured soils."[2] Upper Deerfield Township in Cumberland County is immediately south of the area just described. Its

[1]U.S., Department of Agriculture Soil Conservation Service, New Jersey Agricultural Experiment Station, Soil Survey of Salem County, New Jersey, by Van R. Powley (Washington, D. C.: Government Printing Office, 1969), p. 5.

[2]Leonard Zobler, "Man-Land Relations in Salem County, New Jersey" Ph. D. dissertation, Columbia University, 1953), p. 193.

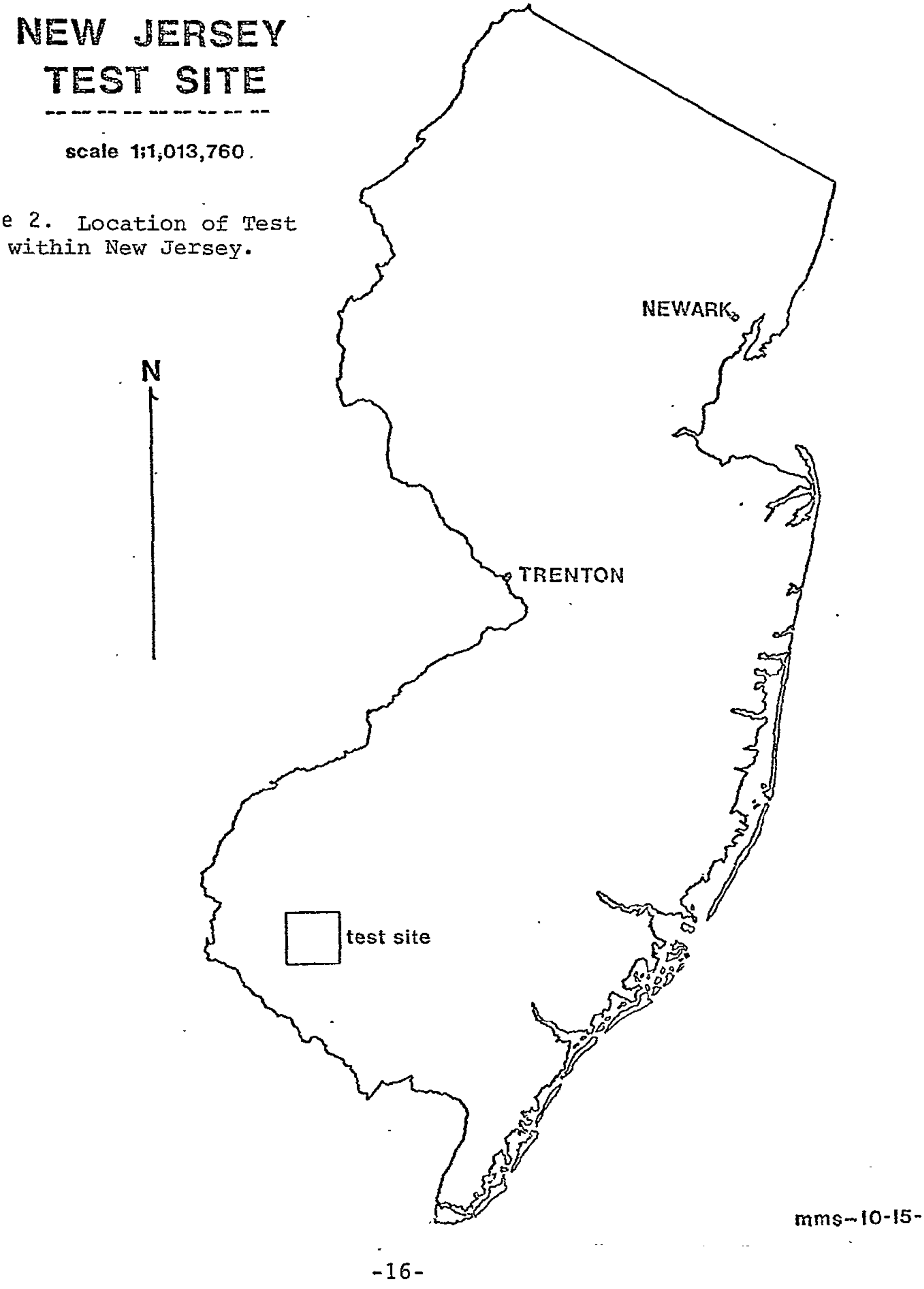
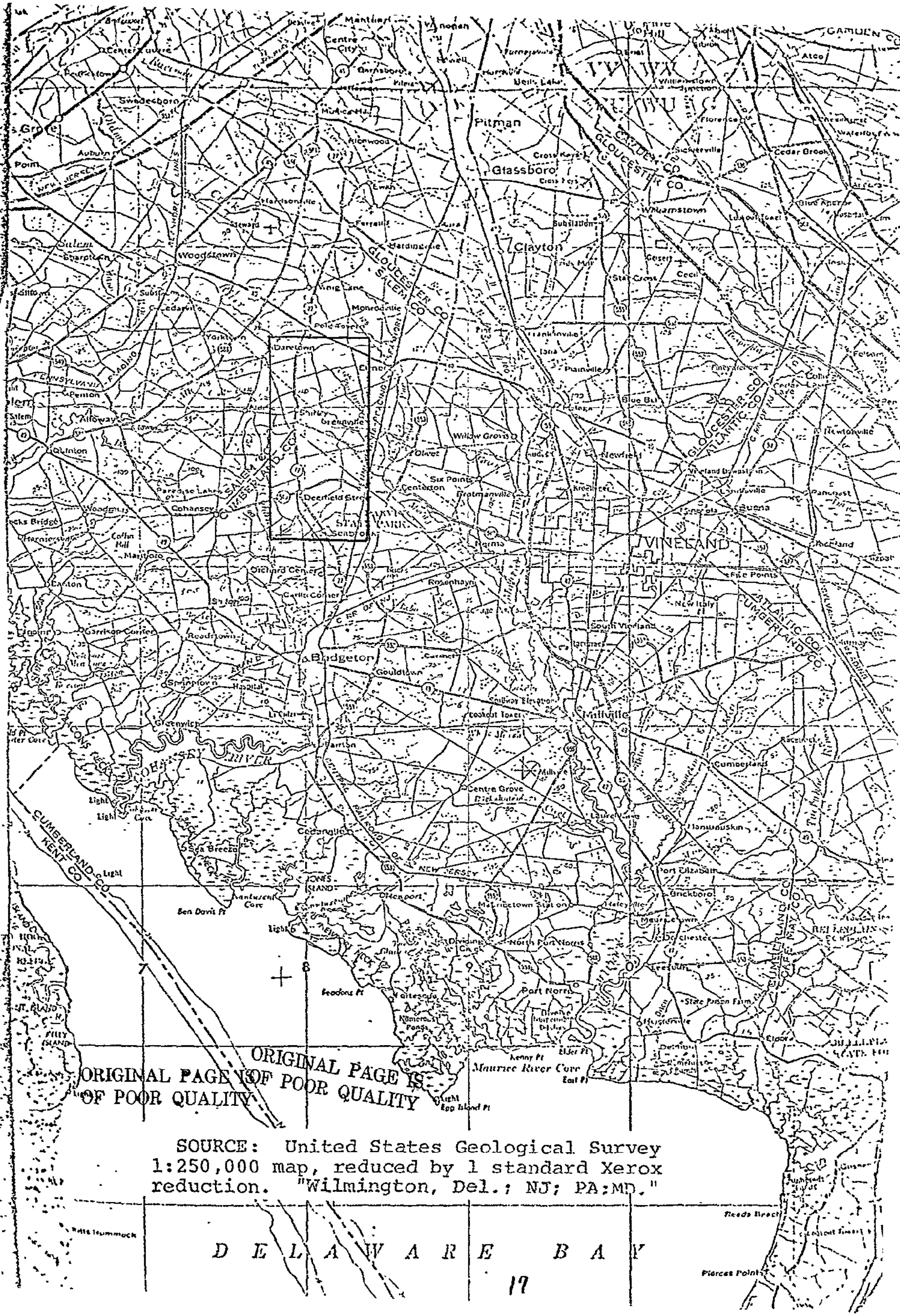


Figure 2. Location of Test Site within New Jersey.

Figure 3. Location of Test Site within Cumberland and Salem Counties.



SOURCE: United States Geological Survey 1:250,000 map, reduced by 1 standard Xerox reduction. "Wilmington, Del.; NJ; PA;MD."

topography and soils share the same general properties. Most of that part of the township with which we are concerned has been placed in the first two classes of the Land Use Capability scheme and is therefore very well suited for agriculture. In 1974, 12,746 acres in the township were devoted to agriculture; the source of the data did not characterize the township in terms of agricultural system, however.[1]

New Jersey's position in the Boston-to-Washington urban sprawl along the east coast of the United States affects its agriculture both positively and negatively. The advantages of its position are obvious in that it lies in close proximity to urban centers which serve as its markets for both fresh and processed foods. The state has been known for many years for its commercial gardening and fruit culture. On the other hand, the nearness to urban centers increases the problems in the areas of taxation, labor, development, and environment, many of which result from competition with urban centers for a comparable standard of living. These problems have had two effects on New Jersey agriculture: (1) the abandonment of farming and the sellout to industry and development, and (2) a gradual change from labor-intensive systems (for example, vegetables and fruits) to more mechanized farming (such as wheat, corn, and soybeans).

[1] Cumberland County Planning Board, Land Use: Existing Patterns and Environmental Characteristics, Upper Deerfield Township, Cumberland New Jersey (Bridgeton, New Jersey: Upper Deerfield Township Planning Board, 1974), p. 35.

Over the past few years, the state's total acreage in vegetables and fruit has declined whereas total acreage in wheat, corn, and soybeans has increased.[1] (See Table 3 for harvested acreage in Cumberland and Salem counties.) These latter crops have always played a part in the New Jersey agricultural system, but their recent acreage increase is indicative of a larger trend. Economic and environmental pressures have forced many members of the vegetable and fruit processing community in New Jersey to move their operations elsewhere. In recent years, Del Monte, P. F. Ritter, and Seabrook Farms have ceased purchasing New Jersey-grown produce. New Jersey farmers have had to find either new markets or new crops; if they choose the latter alternative, field crops are often the most suitable because (1) a farmer can easily convert to this labor-extensive system and (2) wheat, soybeans, and corn have been drawing an increasingly higher price on the market

The approximately 34,000 acres which comprise the test area for this study lie in and around the area formerly farmed by Seabrook Farms, Incorporated, which halted its fresh vegetable processing plant[2] in Cumberland County in

[1]New Jersey, Department of Agriculture, New Jersey Crop Reporting Service, New Jersey Agricultural Statistics, August 1976.

[2]A repackaging plant and warehouse are still maintained by the Seabrook Farms Division of Seabrook Foods, Atlanta, Georgia, a wholly-owned subsidiary of Springs Mills, Inc. The plant and warehouse now handle only bulk frozen produce, however, which has been grown and packed elsewhere.

TABLE 3

ACRES HARVESTED - SELECTED FIELD CROPS

CUMBERLAND AND SALEM COUNTIES

1971-1975

County/Year	Corn	Wheat	Soybeans	Potatoes	Hay
Cumberland					
1971	3,200	2,300	2,900	1,800	3,600
1972	2,850	3,200	2,900	1,600	3,300
1973	3,250	4,000	3,300	1,300	3,600
1974	3,300	4,800	4,200	1,500	3,400
1975	3,600	5,600	4,700	1,200	3,500
Salem					
1971	13,000	3,300	5,000	2,000	10,400
1972	10,200	4,100	6,000	1,800	9,600
1973	11,700	4,900	7,200	1,400	9,700
1974	12,400	8,300	9,000	1,400	9,400
1975	12,900	7,800	9,500	1,000	8,800

SOURCE: New Jersey, Department of Agriculture, New Jersey Crop Reporting Service, New Jersey Agricultural Statistics, August 1972, August 1975, August 1976.

NOTE: Figures on commercial vegetables as a whole were not available on a county basis. The total harvested acreage for all commercial vegetables steadily declined, however, from 93,770 acres in 1971 to 74,760 acres in 1975.

March 1976. This meant that 3,670 acres of their own and 20,000 acres under contract with 150 farmers would be released from their current land uses. All 3,670 acres farmed by Seabrook are included in the test area. The exact locations of the 150 contract growers are not known, but it is assumed that many lie within the test area.

The departure of one processor does not immediately signify a trend; however, in this case the reasons given for such action relate to regional and state problems and are similar in nature to those expressed by Ritter and Del Monte. The president of Seabrook Farms, James M. Seabrook, cited the following causes for the January 1976 decision:

a) The fringe benefits to labor in New Jersey are higher than in the other states where the company operates

b) The farmers' prices for the growth and delivery of vegetables are higher in New Jersey than elsewhere

c) The environmental requirements of the state are difficult to carry out; for example, the Department of Environmental Protection refused a request to burn high-sulfur fuel oil, a measure which Seabrook and others considered necessary economically

d) New Jersey is less pioneering in its research into vegetable problems than California and other states

e) Energy is less costly in other states.[1]

[1]Donald Janson, "Seabrook Farms' Plan to End Processing of Vegetable is Termed a 'Disaster,'" New York Times, 6, January 1976, p. 67.

It appears, then, that the Seabrook action, along with those of Ritter and Del Monte before it, are part of a larger agricultural change occurring in the state. Campbell Soup Company also threatens departure for the same general reasons unless the state and/or the individual growers can be more accommodating. As James M. Seabrook commented on the situation in January 1976, "The future is bleak for vegetable farmers in New Jersey."[1]

This being the case, it is imperative that monitoring of New Jersey agriculture be undertaken. The reasons for such monitoring were outlined in the introduction. Traditional methods must be relied upon for the present; but the New Jersey example points out the potential usefulness of a less time-consuming, less expensive method. A comprehensive land-use study undertaken by the Upper Deerfield Township Planning Board in Cumberland County required eighteen months time, of which six months were involved in data collection.[2] There are thirteen other townships in Cumberland County alone which have yet to begin such a land-use study. Clearly, any assistance which modern data collection tools can offer should be utilized.

[1]Ibid.

[2]Harry R. Dare III, Planning Consultant, Upper Deerfield Township Planning Board, Seabrook, New Jersey, personal communication.

Experimental Design

Crop calendars vary for each type of agricultural system. Vegetables are planted mainly during the warmer months; whereas winter wheat is planted in the fall. Figures 4 and 5 show the planting and harvesting dates for both field crops and vegetables respectively. Based on this fact, the amount of vegetative cover over the course of a year will depend on the cropping system employed.

Vegetation influences the amount of solar energy reflected back from the earth's surface. Green plants, for example, may reflect as much as 95 to 99 percent of the total incident radiant energy.[1] The MSS LANDSAT is sensitive to reflected energy in four bands from .5 to 1.1 microns. Of the four bands, the near-infrared bands are perhaps most sensitive to the maturation of a plant. This is due to the fact that maturation of plant leaves is accompanied by an increase in the number of intercellular air spaces in the spongy mesophyll section of the leaf. Air spaces have been quantitatively related to near-infrared reflectance.[2] In the visible wavelengths reflectance by still-green mature plants is often decreased by the chlorophyll absorption band, which corresponds to the second band on the MSS. This is

[1] David Watts, Principles of Biogeography (London: McGraw Hill Book Company, 1971), p. 14

[2] H. W. Gausman, W. A. Allen, and R. Cardenas, "Reflectance of Cotton Leaves and their Structure," Remote Sensing of Environment 1 (1969), pp. 19-22.

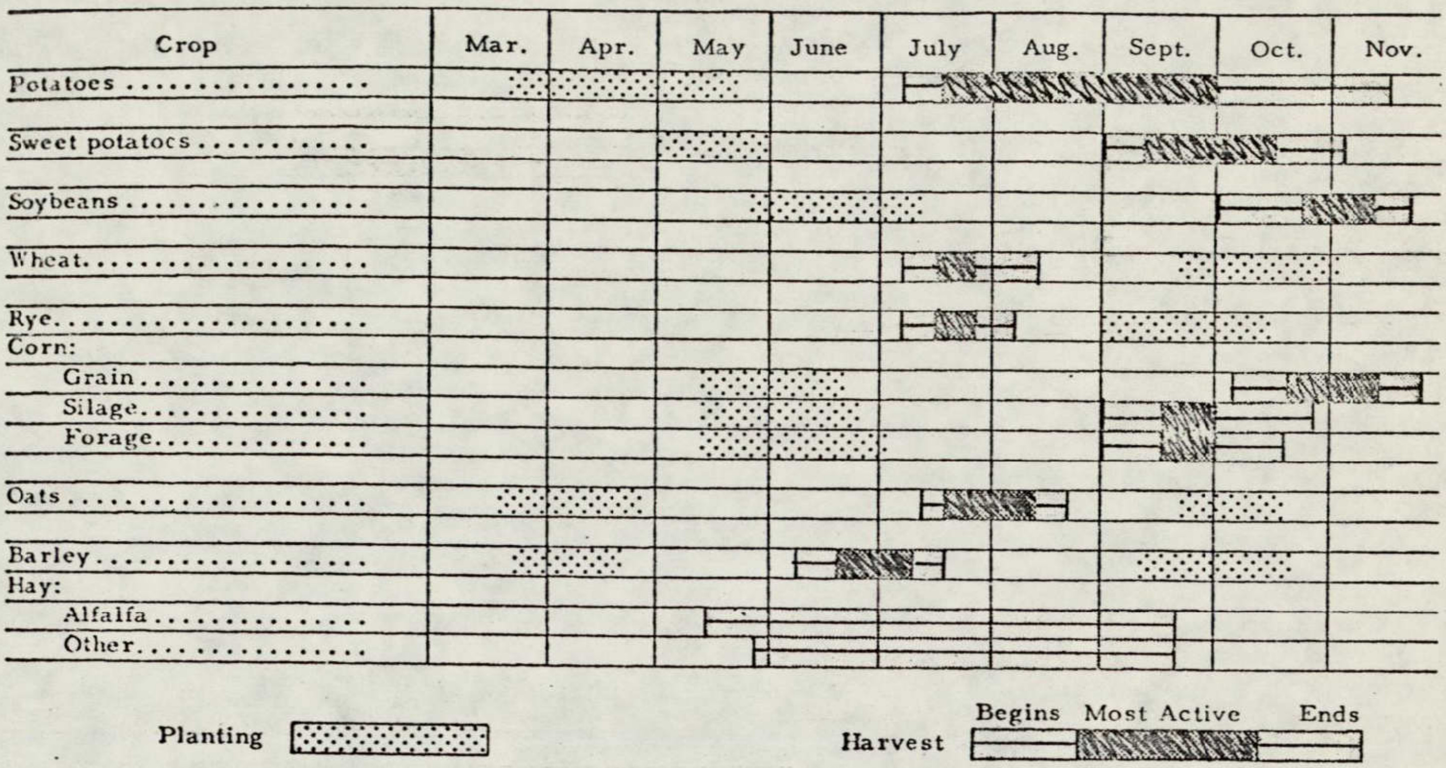


Figure 4. New Jersey: Field Crops, Usual Planting and Harvesting Dates.

SOURCE: New Jersey, Department of Agriculture, New Jersey Crop Reporting Service, New Jersey Agricultural Statistics, August 1976.

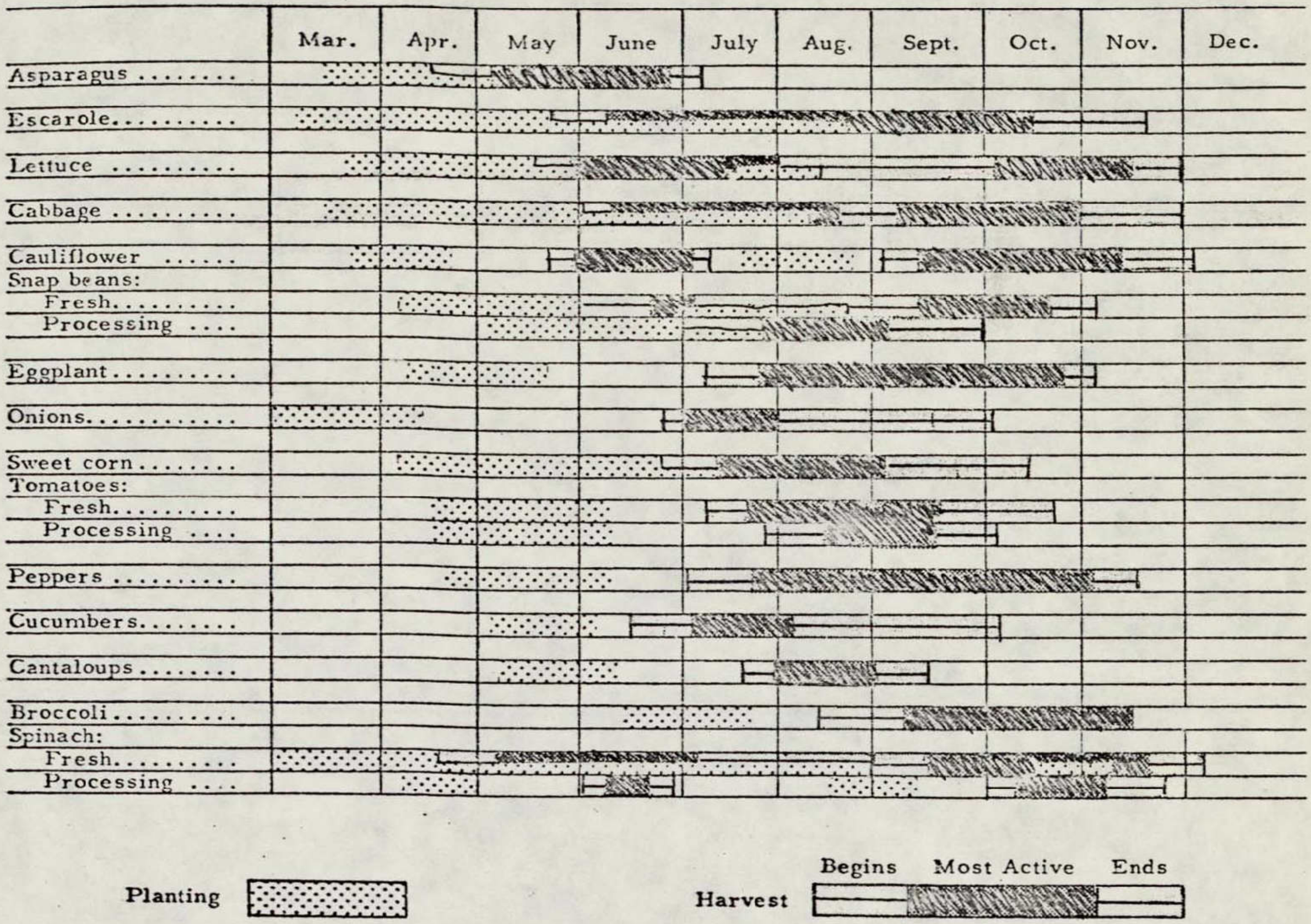


Figure 5. New Jersey: Vegetables, Usual Planting and Harvesting Dates.

SOURCE: New Jersey, Department of Agriculture, New Jersey Crop Reporting Service, New Jersey Agricultural Statistics, August 1976.

borne out by experiments on thirty-two species which show that in the later stages of maturity with less chlorophyll more light is reflected in the visible region.[1]

It is apparent, then, since (1) the spongy mesophyll scatters increasing amounts of near-infrared light as it matures, while (2) the pigmented parts absorb increasing amounts of visible light as chlorophyll increases, that some measure of the reflectance in bands 2 and 4 would be a good indicator of vigorous vegetative cover. In this study, the ratio of Band 4 (second near-infrared) over Band 2 (red) will be used as such an indicator. Similar ratios have been used previously in remote sensing work.[2]

Plotting the ratio of Band 4 to Band 2 (referred to as $R_{4/2}$) on the y-axis against time on the x-axis for a specific ground area will yield a curve for each of the four years of the study. It is hypothesized that a change in curve structure or a shift in the phase of such a curve from year to year represents a change in agricultural system. A mere change in the amplitude of the curve may suggest only an environmental or cropping practice (fertilizer application,

[1] G. I. Pearman, "The Reflection of Visible Radiation from Leaves of Some Western Australian Species," Australian Journal of Biological Science 19 (1966), pp. 97-103.

[2] See, for example, Robert K. Vincent, "Geochemical Mapping by Spectral Ratioing Methods," in Remote Sensing Application for Mineral Exploration, ed. William L. Smith (Stroudsburg, Penna: Dowden, Hutchinson, and Ross, Inc., 1977), pp. 251-278.

tillage operation) change. The year 1976 is particularly important in the Seabrook area; a sharp departure from the curves of the three previous years will indicate a rapid adjustment to the Seabrook Farms decision to cease farming.

It is recognized that MSS data aggregated for a ground area of 1400 acres may not be sensitive enough to adjust to the conversion of one or two fields to a new type of crop. It is in our favor, however, that our study is centered on an area supposedly undergoing transition to field crops. This means that rather large fields may be created from the aggregation of somewhat smaller ones in the change.

It is also recognized that measurements of reflected energy were made at approximately the same time of day but that the sun elevation at that hour changes throughout the year. To account for this difference, a sun elevation correction factor was introduced which, through a sine function, adjusts all measurements to a solar angle of 90°. The use of a ratio also helps filter out solar angle differences.

This analysis will employ digital LANDSAT data and rely upon, as support materials, LANDSAT imagery, aerial photography, United States Geological Survey maps, and ground-collected information.

Although LANDSAT data are available for passes made every eighteen days from July 1972 to January 1975 and every nine days from January 1975 through most of 1976, not all of them are usable. Adverse weather conditions such as thick haze or cloud cover over the area of interest make certain passes unsuitable for analysis. Other technical problems preclude the transformation of data from certain passes into computer compatible tapes. Twenty-five tapes are found to be both free of such problems and geographically appropriate to this study. These will be preprocessed for geometric correction and rectification to a Universal Transverse Mercator grid.

Imagery is used to choose suitable passes and to locate oneself in the digital data. A block of data over a geographic area of approximately 100 square miles is called a "scene." From each scene are chosen twenty-four smaller areas of about 1400 acres apiece which will be used as the unit of analysis; this 1400-acre area is called a "quad." Each set of twenty-four quads coincides spatially from scene to scene. Therefore, we are looking at the change in reflectance of twenty-four identical areas over the course of four years - 1973 through 1976.

An unsupervised classification routine developed at the Institute for Space Studies is used to obtain an average spectral response for each quad. Normally, this routine is used to delimit clusters of pixels which correspond to some land-cover class. In this experiment, however, the object is to delimit one large cluster into which approximately 95 percent of the pixels fall. This percentage is chosen to filter out any exotic pixels which might influence the quad's spectral response out of proportion to their actual land area. The unsupervised routine is, therefore, applied to twenty-four quads from each of twenty-five passes to obtain 600 characteristic spectral responses in four bands.

The reflectance measured in bands 4 and 2 will be ratioed - $R_{4/2}$ - and this ratio will then be plotted, quad-by-quad on the y-axis, with time on the x-axis. The data will be analyzed using a time-series analysis.

Results

Only preliminary results are available, since the data processing has not been completed. Table 4 shows some sample quads and their $R_{4/2}$ ratio for some of the data of 1975-1976.

TABLE 4

FOUR QUADS AND THEIR BAND 4/BAND 2 RATIOS

FOR SELECTED DATES IN 1975-1976

Date	Quad			
	1	2	3	4
18 Nov '75	3.23	2.55	3.08	2.78
19 Apr '76	3.49	2.90	3.41	2.85
12 Jun '76	3.37	3.38	3.37	3.37
18 Jul '76	6.26	7.41	5.60	6.48

2. Interrelationship Between National Crop Yields. (E. Matthews)

A correlation and multivariate analysis of 25 years of country by country crop yields has been undertaken to determine the spatial relationships involved in global yields of small grains (wheat, rice, millet and barley). The purpose of the study is to determine if patterns of variation exist on a global basis and if these patterns are reflected in the existing network of grain exchanges. This study is important to satellite monitoring of crops to establish key areas where deficits and supluses of food are generated.

D. Traditional Agricultural Systems

Shifting Cultivation in Kenya. (T. Cary)

An investigation into the feasibility of detecting shifting cultivation in East Africa has encouraging preliminary results.

The study site is in the West Pokot District of Kenya. LANDSAT computer-compatible tapes for three dates are available: scene 1067-07221, 9 September 1972; scene 1193-07230, 1 February 1973; and scene 2063-07111, 26 March 1975.

Supplementary data include 1956 black-and-white aerial photography and data from 1961-62 anthropological fieldwork.

Using these data in conjunction with gray scale printouts of geometrically corrected LANDSAT data, a preliminary study site was selected. A ten-hectare training area in the locally-designated Asar region always contains active cultivation. From this area, the most frequent spectral response in each band was determined, and this became the training data (Table 5). The preliminary study site was classified in each data set into two categories: each data point was or was not in the same category as that defined by the training spectral response pattern and the program parameters.

Distribution of points put into the category defined by the training data was well-correlated with the ecozone in which shifting cultivation occurs. The percentage of classified points falling within the ecozone was 77%, 82%, and 80% for the three dates. This led to the inference that the defined training class does represent shifting cultivation.

The same training data were then used to classify a larger area (2380 ha). Results are being interpreted.

TABLE 5

MODEL RESPONSES USED FOR TRAINING

Scene ID	Date		Responses Band 4	Band 5	Band 6	Band 7
1067-07221	9/28/72	count	29	22	46	24
		energy*	.566	.346	.637	1.752
1193-07230	2/1/73	count	28	26	43	24
		energy	.547	.409	.596	1.752
2063-07111	3/26/75	count	30	36	54	27
		energy	.572	.492	.636	1.859

*$mw/cm^2 \cdot sr$

E. Agro-Environmental Research

1. Impact of Environmental Parameters on Computer Classification of Agricultural Land Use (S. Lytle)

Current research in computer classification of remote sensing techniques concentrates on acreage estimation of agricultural land use. The techniques used for acreage estimation identify and then separate radiance values of the scene into categories. These values are usually considered discrete elements of the environment, and no attention is given to their composition. Another way of examining the spectral response of any landscape is to view it as a composite of human management and physical environmental characteristics, which make varying contribution to the landscape's radiance. It is the purpose of this research to assemble major environmental parameters into a model measuring their influence on spectral signatures of an agricultural landscape. The investigation is based on a LACIE intensive study site in the northern Great Plains, and data acquired by Johnson Space Center 24-Channel multispectral scanner.

The computer classification used in this digital analysis consists of two major elements: 1) the ground truth system implemented and 2) the radiance values of the landscape. The first element divides the scene into finite geographic units of varying sizes and shapes (i.e., agricultural fields, soil boundaries), and the second element represents the spectral response of the environment. It is the function of the classification algorithm to distinguish between and assign each pixel to its respective land use category. A change in the ground truth system results in classification of the same landscape into different land use categories. This may reveal a higher incidence of homogeneity within a category, resulting in higher classification accuracies and a more thorough understanding of the spectral reflectances.

In agricultural studies, two categories of environmental parameters are identified: human management and physical environment. Human management consists of such farming practices as tillage direction, fertilization, planting date, and irrigation. The physical environment category includes elements such as soil type, soil color, and terrain slope. The relative influence of a set of parameters on land use classification is unique for each landscape.

The study region for this investigation is a 5 x 7.5 kilometer area of Williams County, North Dakota, where severe winters and dry summers predominate. Spring wheat is the major crop in a landscape intermixed with summer fallow and pasture fields. Summer fallow is practiced almost exclusively as an anti-wind erosion measure in strip cropping patterns. Pasture includes harvested and non-harvested oats and other natural grasses which may or may not be grazed. The agricultural practices are impacted to some extent by remnant glacial features, such as potholes and till knobs. Potholes create areas of poor drainage which become marshy during stages of evaporation after the rainy season. Sections of patchy bare soil (till knobs) produce a mottled effect in the appearance of the landscape.

The human management practices and physical environmental factors of this area comprise a landscape system of varying spectral response. Explanation of the spectral variability will be attempted through the testing of eight environmental parameters as separate ground truth systems. These parameters are as follows:

1) tillage direction
2) planting date
3) fertilization
4) soil type
5) soil color
6) soil brightness
7) soil texture (A-horizon)
8) terrain slope

Construction of the ground truth files will differ between the two major categories. Aspects of human management (parameters 1-3) are field dependent and each will be input through a field number ground truth array. Each set of farming practices can then be substituted for a classification experiment. In contrast, the spatial distribution of physical environmental factors is independent of fields and a separate ground truth file must be created for each.

Construction of a model based on a series of test results should reveal the relative influence of each parameter upon the classification categories. It is expected that each parameter will have differing magnitudes of influence, both within and between each category; however, the degree of distinguishability is not anticipated.

APPENDIX A

AN EXPERIMENTAL APPROACH TO A SETTLEMENT PATTERN STUDY

Paper presented at the
annual meeting of the
American Anthropological Association
Washington, D.C., November, 1976

by

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AN EXPERIMENTAL APPROACH TO A SETTLEMENT PATTERN STUDY

ABSTRACT

Due to the great time depths that archaeologists work with, the establishment of a time/space framework is of fundamental importance to archaeological research. The purpose of this paper is to examine the integrated use of satellite data, standard aerial photography and field work to establish a time/space framework in the initial stages of planning and implementing a rural settlement pattern study of the Jequetepeque valley on the north coast of Peru.

Of fundamental importance to archaeological research is the long range view of human development. To accomplish the fullest possible understanding of prehistoric cultures and cultural processes rigorous research strategies, excavational techniques and analytical procedures are employed. The ability to place artefactual and non-artefactual data in a time/space framework is crucial to archaeological research. Without knowledge of geographic and contextual information, and, of course of sequences of events in time, interpretation would not be possible. Therefore, the control of temporal and spatial information are basic to archaeological research as little can be accomplished without it.

In the initial formulation of a prehistoric settlement pattern study of the Jequetepeque valley, (sometimes called the Pacasmayo valley), on the north coast of Peru, it was felt that an attempt should be made to establish preliminary ecological, spatial and chronological frameworks for the sites in the valley. Subsequent stages of research would involve a general field survey and selected excavations to establish: specific occupation chronologies; site functions; and economic activities (through the analysis of subsistence remains). In doing so, such data would be integrated in a larger system of analysis.

A traditional technique employed by archaeologists has been the interpretation of standard aerial and ground photography to gain a greater overall perception of the phenomena under investigation. In recent years the use of such data by anthropologists has, in part, contributed to the design and formulation of research projects, and to a rapid method of hypothesis testing. This has been true specifically in the recognition and comprehension of spatial patterns apparent in the interaction of cultural phenomena and the environment (e.g. Bruder et al, 1975; Coe, 1974; Coe & Flannery, 1964; Hackenberg, 1974; Harp, 1974; Methany, 1976 Kaplan, 1976).

Such studies have relied primarily upon the knowledge and skill of the individual photo (image) interpreter for the visual recognition of comprehendable patterns apparent in the photographs. Identified phenomena were then verified by field observations. In certain portions of the world photo coverage of relatively large areas necessary for this approach is not readily available, as is the case in Peru. Moreover, photo mosaics of extensive areas are unwieldly to handle, and scalar inconsistencies resulting from altitudinal fluctuations of the aircraft are time consuming and difficult to relate to available maps.

In reviewing the published literature relating to the Jequetepeque valley, only scant references were found. Cieza de Leon (1553) and Father Antonio de la Calancha (1638) provide limited insights to the late prehistoric times. Early explorers had visited and described the more prominent ruins on the Peruvian north coast (E.G. Squire, 1877; A. Bandelier,1893). References to larger archaeological ruins are found in several general surveys by a number of archaeologists (Kroeber, 1930; Schaedel, 1951; Ishudi et al, 1960; Kosok, 1965; Keatinge, 1975; Keatinge & Chodoff, 1975). (see fig 2.) Furthermore, the results of archaeological investigations which included excavations in the Jequetepeqeu valley have only been published for two sites: San Jose de Moro (Disselhoff, 1956, 1958a, 1958b); and, Pacatnamu (Ubbelohde-Doering, 1951, 1959, 1960, 1967). As a result of the limited information available pertaining to prehistoric sites in the valley another approach was sought to facilitate the location of specific phenomena in their spatial context rapidly and efficiently.

Satellite imagery has been available from ERTS I and II (known as LANDSAT I & II prior to launch) for the last four years, and its use provides a broad overview of social environmental interaction (Conant et al, 1975). More importantly though, due to its digital format based on perceived patterns of reflected light integrating data from four sequential portions of the electromagnetic spectrum, (from .05 micrometers to 1.1 micrometers)[1], computer manipulation of the data is the most efficient way of fully exploiting this data source (pers. comm., J.C. Coiner). Numerous investigators have demonstrated the diverse potential that this methodological technique offers. Examples of such applications include: the classification of land use, and the discovery of mineral resources (Anderson, n.d.; Bernstein & Ferneyhough, 1975; Collins, 1976; Wilson & High, 1976); livestock management (MacLeod, 1974); the classification and forecasting of crops (Hammond, 1975; Webb et al, 1976); and, the development of demographic models (Foresti & DeMendoca, 1974; Hsu, 1973). Recently several anthropologists (Cook & Stringer, 1974; Fanale, 1975; Reining, 1975) have begun to test the potentials that the digitalized satellite data presents for their research in terms of: mapping microenvironments; quantifying land use and settlement features; and discerning man/land relationships intrinsic in land use patterns.

As this remote sensing technique offered the advantages of locating and quantifying specific phenomana rapidly and efficiently in their spatial contexts (AGA Workshop, 1976), an attempt was made to integrate regional satellite data, available aerial photography, and published data in the initial formulation and dseign of a prehistoric settlement pattern study of the Jequetepeque valley. The aims of this research were to define distinct environmental zones, and to locate and plot archaeological sites prior to entering the field. Furthermore, it was hoped that spectral diffences could be perceived distinguishing such archaeological features as canals, human settlements and associated features on the basis of differing and distinct materials (e.g. the constituent percentages of adobe and stone present at various sites). Thus, establishing a spatial framework for surface sites in their environmental milieus. The results of such research might provide chronologic settlement insights in terms of locational choices and construction materials used in different prehistoric time periods. Another interesting implication of such a study is that, if successful, time and money could then be utilized more efficiently by the archaeologist in the field to concentrate on testing locational hypotheses and other aspects of field work.

After defining the Jequetepeque valley on LANDSAT imagery (see plate 1) (scale 1:1,000,000) an algorithm developed at the Goddard Institute for Space Studies (GISS)[2] was used to generate a computer printout greyscale (nominal scale 1:24,000) delimiting maximum resolution cells ("pixels" or picture elements, approx. scale 57x79meters, or .45 hectares) (see plate 2). Then the mathematically described reflectance "signatures" taken from pixels containing known phenomena were derived. In this case the signature was derived from the site of Farfan in the Jequetepeque valley (see). A computer search was then instigated to locate similar signatures in similar environmental settings in the valley, resulting in a printout of the aereal distribution of pixels containing similar signatures. (see plate 5).

Field observations ("ground truth") were necessary to support the available data and to aid in the refinement of the computer analysis. In the summer of 1976 I visited the Jequetepeque valley to begin a preliminary reconnaissance of archaeological sites, and to collect the field observations needed to augment the remote sensing research[3].

The preliminary results suggests that the LANDSAT data is useful for mapping and estimating the extent of cultivated and naturally vegetated land in the valley. However, it proved extremely difficult to discriminate architectural sites based on their spectral reflectances alone. This is not surprising as significant problems were encountered both in the computer analysis and in the field which rendered this remote sensing technique unsuitable for this study.

The first problem lies in the lack of adequate LANDSAT coverage of the north coast of Peru. Only two images are available which include the entire Jequetepeque valley. The first of which contained sporadic cloud coverage. Unfortunately, the largest and most densely featured site, Pacatnamu, was entirely covered by clouds, thereby, eliminating the possibility of deriving the most reliable signature from this site. The second image was totally unusable for the entire coastal region was blanketed with clouds.

The degree to which the radiometric return representing archaeological sites and their surrounding environment on a pixel to pixel basis presented the second problem. The Jequetepeque valley is located in one of the driest regions of the world (Cornejo, 1970). It lacks dense vegetation with the exception of those areas presently used for wet rice production. The vast majority of prehistoric sites are relatively small in comparison to the size of the pixel, and they occur in dessicated areas along the valley margins and on hills. As the sites sought in the LANDSAT data occupy varying fractions of the pixels in which they occur, and do not present sharp contrasts with their surrounding environments, their detection was difficult. Furthermore, LANDSAT data acquisition occurs at 9:42 a.m. (local time) on a worldwide basis (Conant et al, 1975). The result is that shadowing effects from standing architecture which might help in site identification is held to a minimum due to the Jequetepeque valley's close proximity to the equator.

Because of these problems, the results were mixed. It was found that some of the pixels classified as potential prehistoric sites in the preliminary classifications were accurate, while many other pixels in the same category were not. They were areas which only contained materials and/or natural features similar to those found at archaeological sites (e.g. gravel, some scattered vegetation, crusted soil resulting from pools of standing water formed by the infrequent torrential rainfall etc.).

Though the evidence mitigates against the present use of digitalized satellite data for the research attempted, it appears that with cloud free imagery and smaller pixels this approach is a feasible one. As spectral contrasts are essential in the recognition of specific phenomena, it should be stressed that the problems encountered in this study are area and phenomena specific. Therefore, it is felt that time/space frameworks can be established using satellite data facilitating contextual, functional and processual analyses, and, may contribute to the generation and testing of new hypotheses.

Notes

1. .5-.6 micrometers represents the green portion of the visible spectrum. .6-.7 micrometers represents the red portion of the visible spectrum. .7-.8 micrometers represents the first near infrared band. .8-1.1 represents the second near infrared band.

2. This research was conducted under NASA grant #5080 using facilities provided by the NASA Goddard Institute for Space Studies.

3. This research was supported by the Institute of Latin American Studies, Columbia University, Tinker Foundation Graduate Summer Field Training Fellowship.

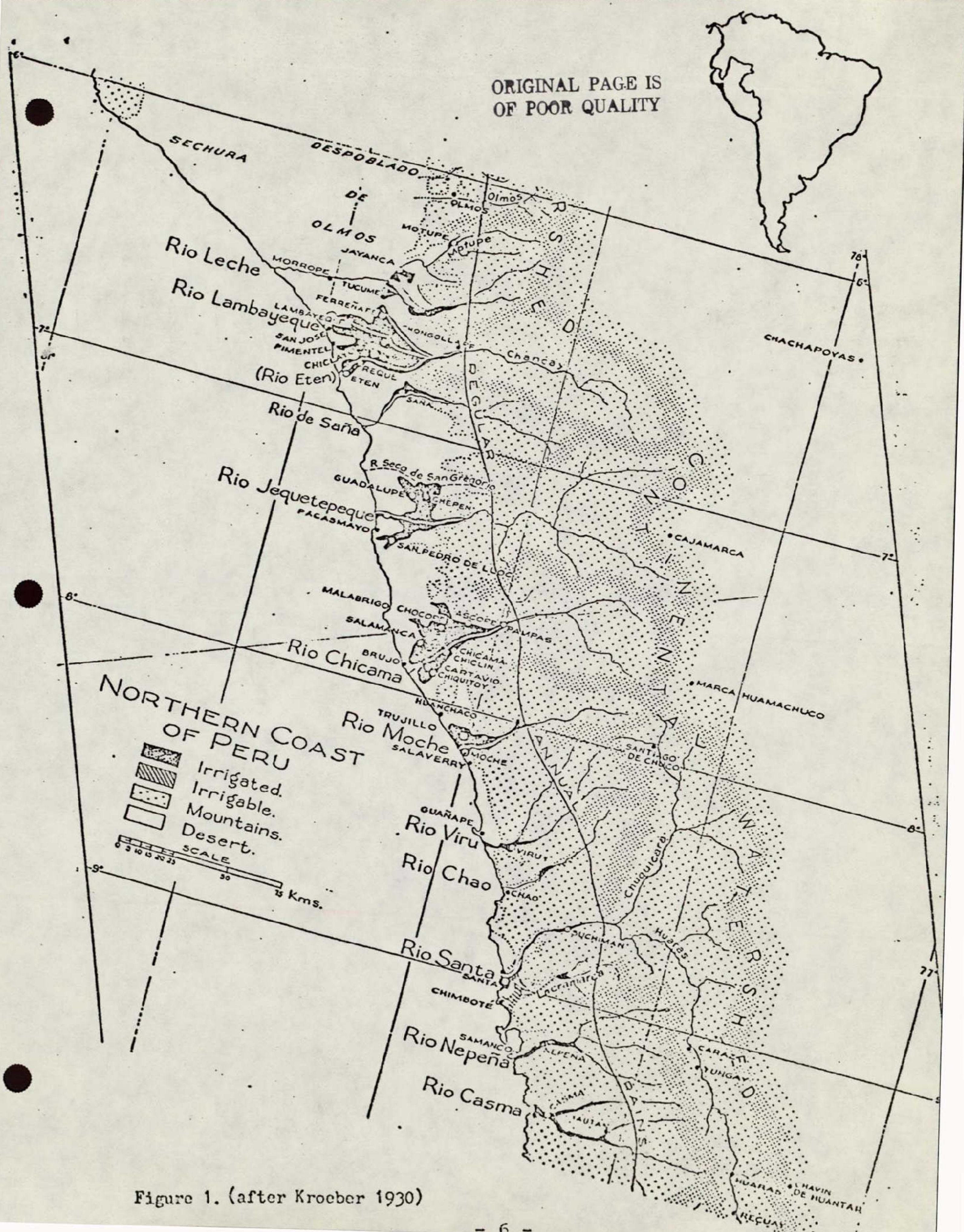

Figure 1. (after Kroeber 1930)

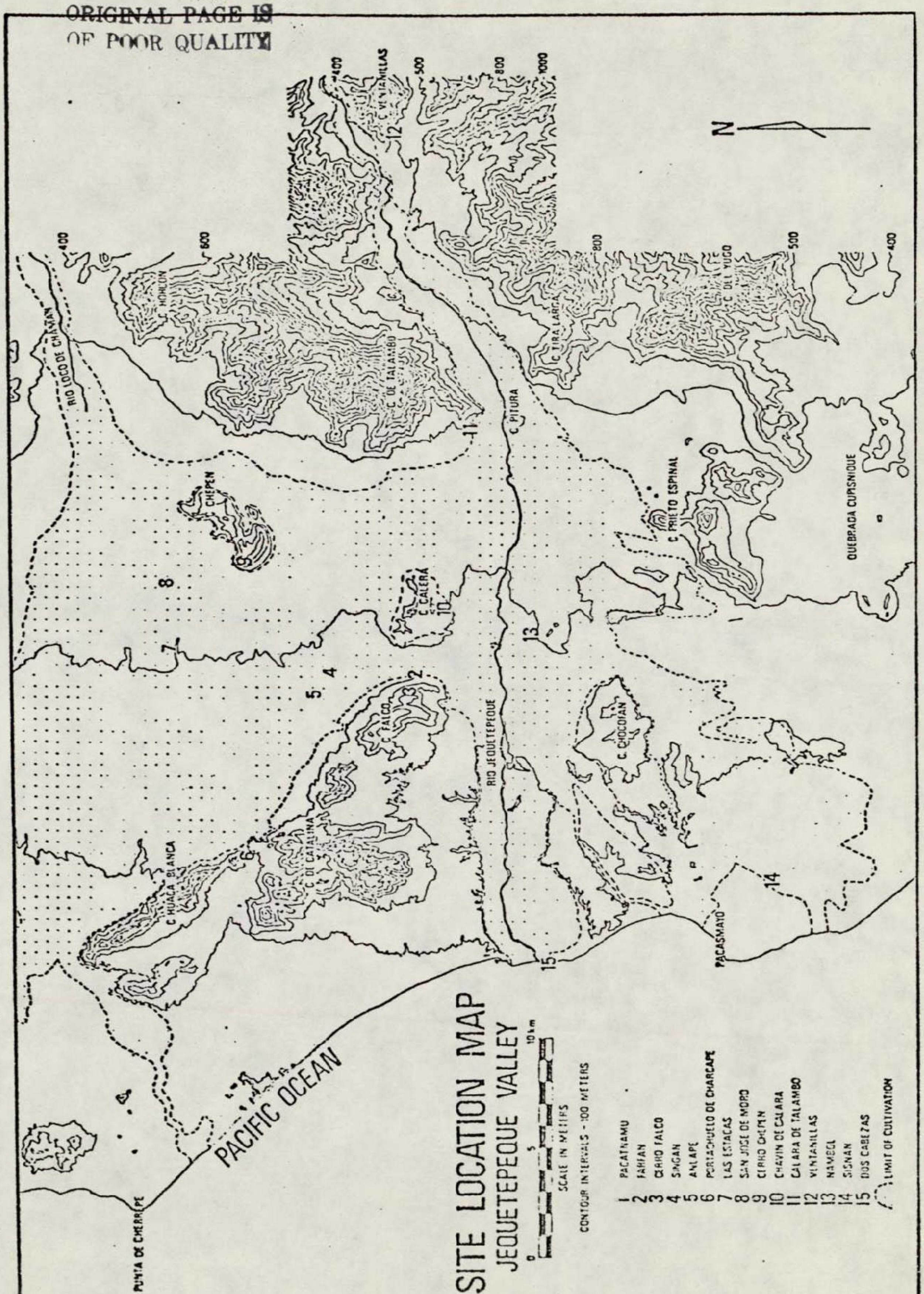

Figure 2: Map showing the location of sites surveyed during the summer of 1974 (after Keatinge & Chodoff 1975.)

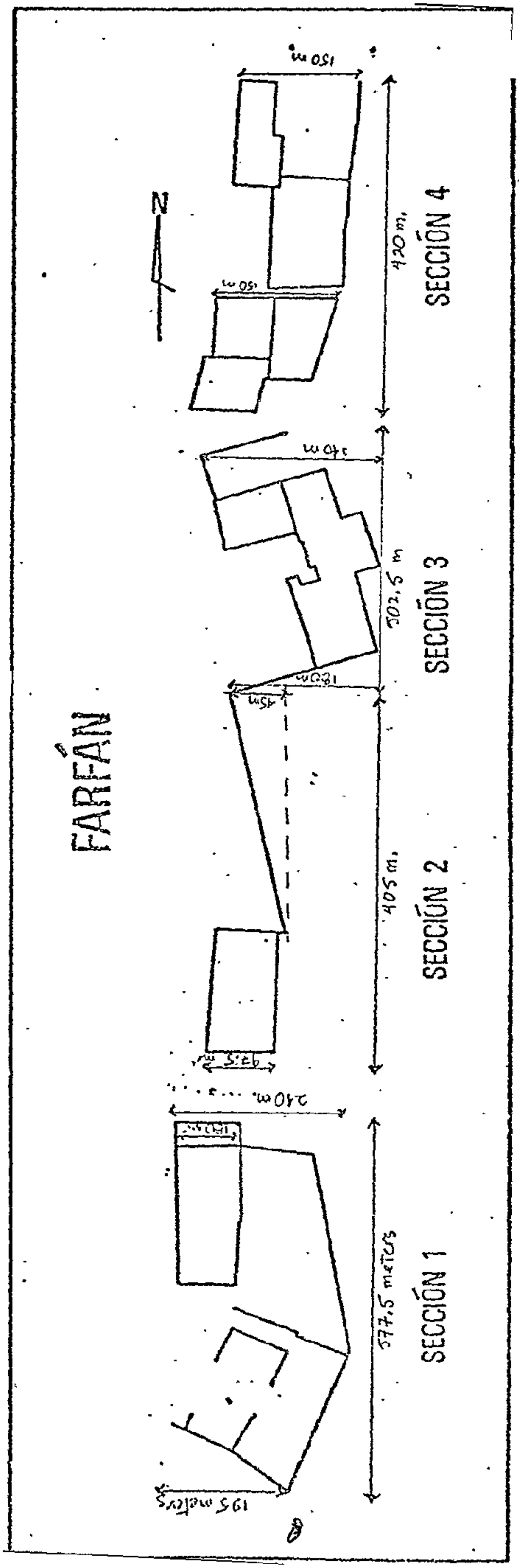

Figure 3: Floor plan of the site of Farfan (pers comm., Løstanau.)

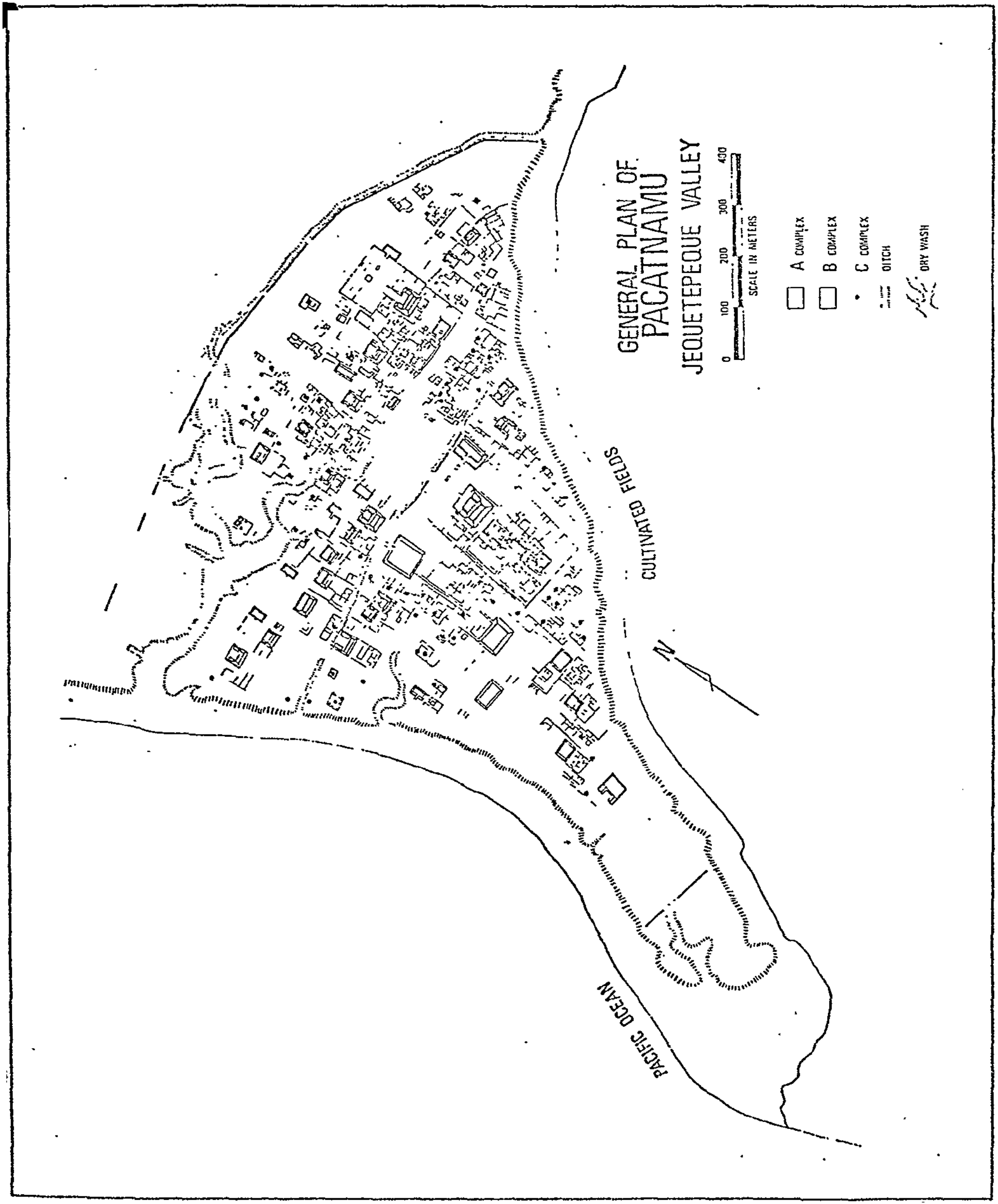
GENERAL PLAN OF
PACATNAMU
JEQUETEPEQUE VALLEY
0 100 200 300 400
SCALE IN METERS
A COMPLEX
B COMPLEX
C COMPLEX
DITCH
DRY WASH
CULTIVATED FIELDS
N
PACIFIC OCEAN

Figure 4.

Jequetepeque
Valley, Peru

Plate 1. LANDSAT color image of the Jequetepeque Valley, Peru,

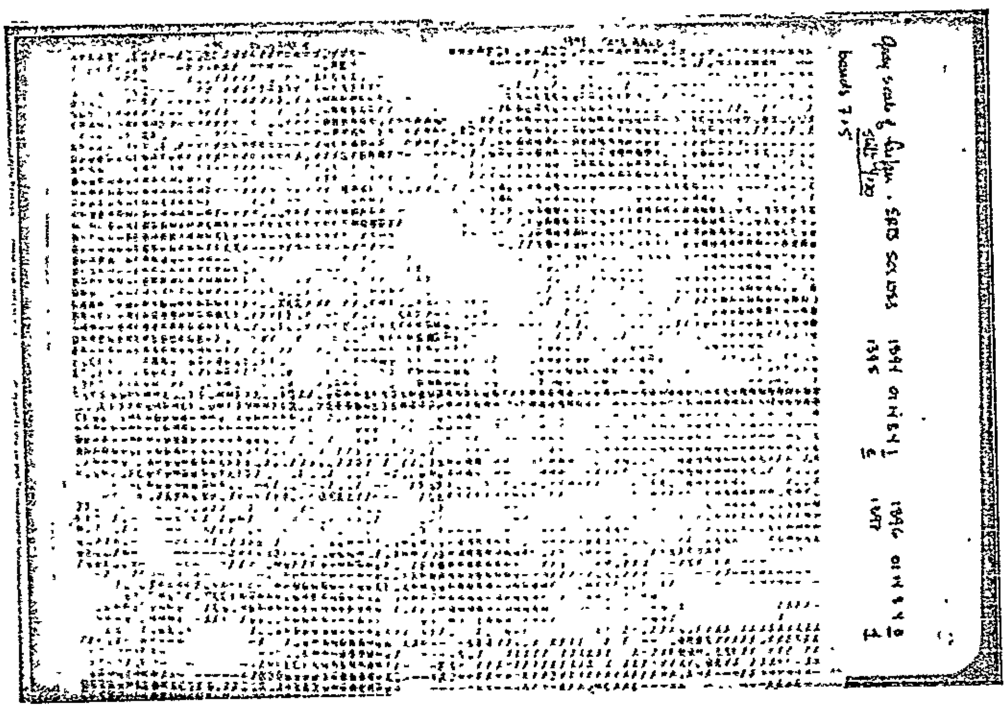

Plate 2. Computer greyscale printout of a portion of the Jequetepeque Valley, Peru. Linear feature outlined in red corresponds to the Pan American highway which is adjascent to the archaeological site of Farfan.

Plate 3. Aerial photo of the site of Farfan in the Jequetepeque Valley, Peru. The linear feature seen on the air photo is the Pan American highway. Standing wall architecture can be observed to the right of the Pan Am. Wet rice fields abutt the site to it's right, and Cerro Faclo lies to the left of the site. (Servicio Aerofotografico Nacional, Lima, 1968.)

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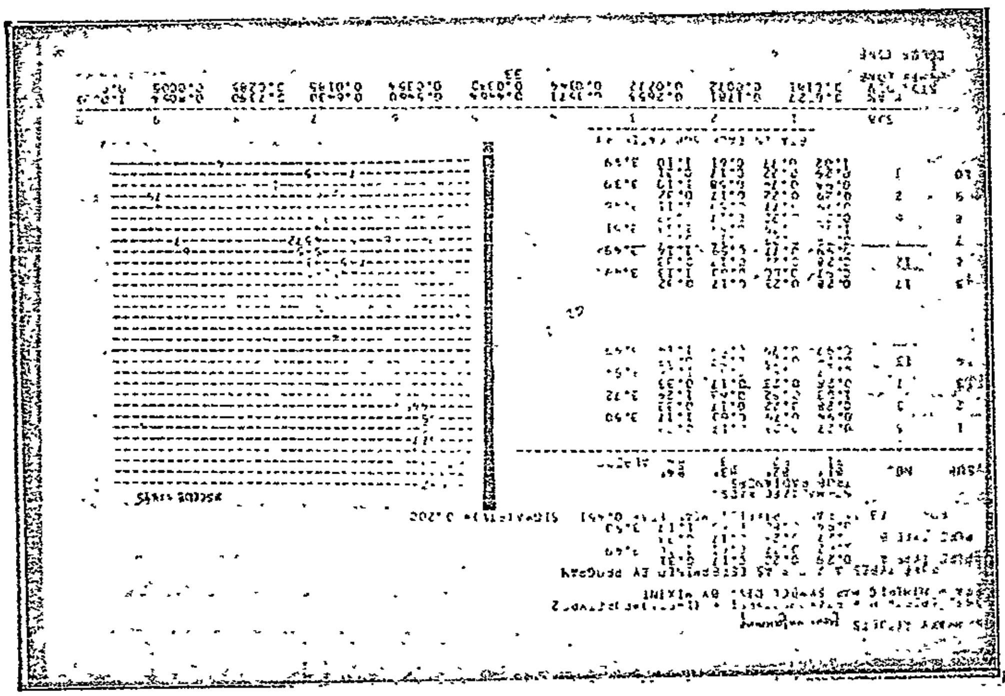

Plate 4. Refined computer greyscale printout based on a mathematically described reflectance signature delimiting the known archaeological site of Farfan.

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OF POOR QUALITY

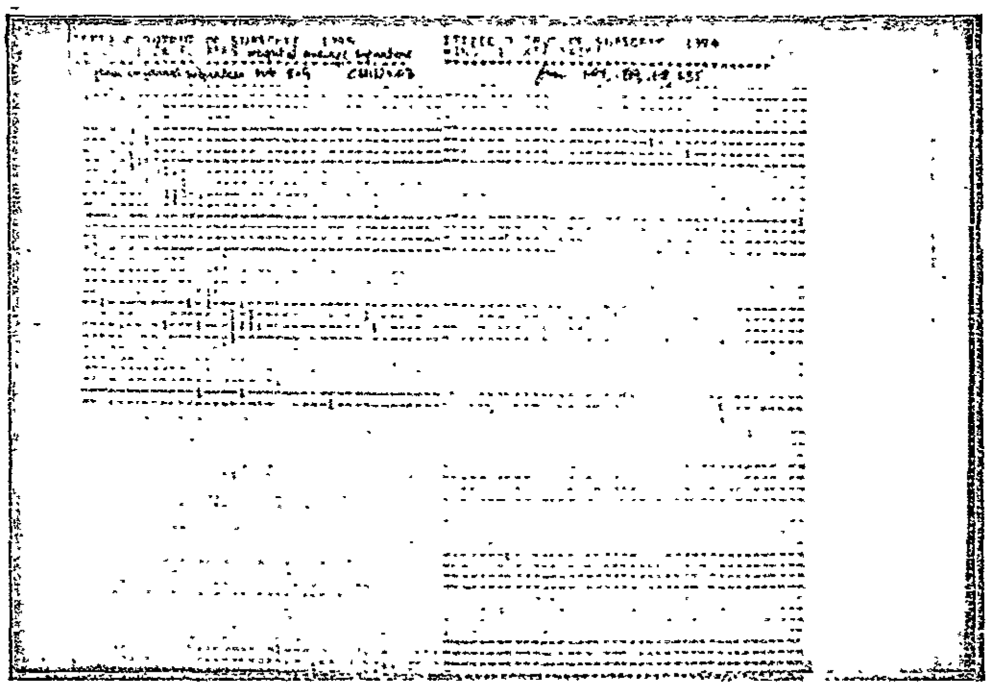

Plate 5. A portion of a computer printout utilizing mathematically described reflectance signature derived from the archaeological site of Farfan. The cluster of pixels in the upper left portion of the plate corresponds to the archaeological site of Farfan. Note the scattered aerial distribution of similar signatures throughout the plate.

Plate 6. Enlargement of LANDSAT color image of the Jequetepeque Valley, Peru. Red arrow indicates the location of the archaeological site of Pacatnamu. Note the sporadic cloud coverage of the valley at the time of data acquisition.

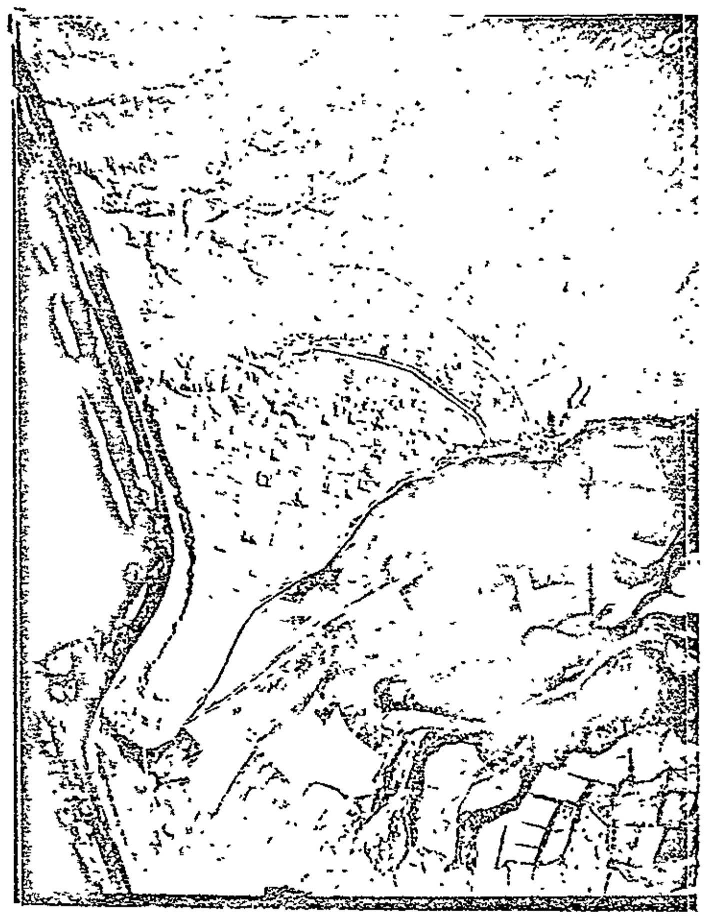

Plate 7. Aerial photo of the archaeological aite of Pacatnamu in the Jequetepeque Valley, Peru.
(Servicio Aerofotografico Nacional, Lima, 1944.)

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Columbia University in the City of New York | New York, N. Y. 10027

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PHOTOINTERPRETATION SUPPORT OF SPECTRORADIOMETER AGRICULTURAL STUDIES

Nancy M. Lytle

December 6, 1976

Work Conducted under NASA Grant NSG-5080/2

21 a

PREFACE

Photointerpretations presented in this document were made at the request of NASA, Goddard Institute for Space Studies for incorporation in a Crop Spectra Atlas being prepared under the auspices of the Institute's Earth Resources Program.

Photointerpretation support of spectroradiometer agricultural studies conducted by NASA/Goddard Institute for Space Studies involved interpretation of the aerial coverage of two sites of irrigated agricultural land in the Imperial Valley, California. One site is located in the southern part of the valley near the town of Calexico, while the other is located in the eastern-central portion of the valley. Together, they encompass approximately 6 square miles of crop land. The crop types include both continuous-cover crops, such as alfalfa, wheat and barley, and row crops, such as sugar beets, mellons, onions, carrots, sorghum and cotton. Dates and times of the flight are listed in the following table:

Flight Number		Flight Time (Duration)
Flight 2	May 15, 1975	9:28 AM - 10:42 AM
Flight 3	May 16, 1975	9:54 AM - 11:03 AM
Flight 5	May 20, 1975	10:55 AM - 11:15 AM
Flight 1	September 23, 1975	10:26 AM - 11:30 AM

The purpose of the photointerpretation was to support and clarify the spectroradiometer data and to supplement the ground truth by uncovering broad and extensive patterns which are unrecognizable in field work.*

---

*Spectroradiometer and 35mm simultaneous photo data acquired by Dr. William Collins to support NASA/Goddard Institute for Space Studies Earth Resources program.

An intensive interpretation was performed on 280 individual fields using 35 mm (strip) color transparencies, at a scale of 1:20,000. These strips were acquired simultaneously with the spectrophotometric data. The coverage of the fields encompassed 840 frames with approximately 60% overlap. Bausch and Lomb Zoom 240 optical equipment was utilized with varying magnifications, ranging from 4 to 7.5X, according to the image characteristic under examination.

Each field was classified using the following set of image characteristics:

PHOTOINTERPRETATION IMAGE CHARACTERISTICS

Tone	homogeneous inhomogeneous
Texture	none or absent fine medium coarse differential--range
Density	bare soil low medium high differential--range
Cover	bare soil little 1/3 2/3 near total total
Crop Status	growth stage, unusual patterns or conditions, and ripening description for wheat and barley fields
Furrow Direction	parallel or perpendicular to Flight Line

In order to further understand the categories of classification, a definition of each is necessary. It should be noted that the elements of interpretation are difficult to categorize because they are completely interrelated, but a distinction is mandatory for the purpose of classification.

When examining tone, fields were classified according to their homogeneity. If the tone was interrupted because of contrasts due to ripening, visibility of bare soil areas, soil moisture patterns, or any other crop condition, the field was graded inhomogeneous.

Texture results from differential height in the crop. For example, a coarse texture is present when growth is sporadic, harvesting is in progress, or when a crop, such as mellons, is in an early growth phase and height difference between the clusters of plants and bare soil is large. Texture is absent or fine when the crop has smooth and uniform cover, or when the field contains bare soil. In those fields where texture was differential, the range was specified and exceptions were mentioned.

Both density and cover are descriptions of the amount of soil that is visible in the field, however, it is quite possible for a crop to have total cover but medium density, for example. To clarify the difference between terms, density is basically the number of plants per unit area and describes the thickness of the crop and how closely planted it is. Crop cover is more a description of the growth stage and vigor of the crop. If a crop is stressed, the cover can be spotty and discontinuous while a healthy (unstressed) crop will tend to have total or near total cover. Likewise, newly planted crops have very low cover while mature crops tend to have total cover.

The classification of furrow direction was very straightforward. The furrows either ran parallel or perpendicular to the flight line. However, the term "furrow" should be further defined since it is used loosely to refer not only to furrows but also to crop rows and irrigation control ridges in continuous-cover crops. In some fields, the crop density was so high that the furrows were not visible. In these cases, no mention was made of their direction.

Any unusual pattern or conditions fell under the crop status category. These included such things as ripening stages, and irrigation, growth, or soil moisture patterns. The location or size of these patterns was identified in terms of ground distance and proximity to field boundaries. Also, the possible reasons for unusual conditions were often mentioned.

A complete text of the photointerpretation is included in the following pages, organized by flight line and showing frame reference data to the right of the interpretation. Frame reference data elements in order are: location, time, date, data set, data location, and roll-frame.

FLIGHT LINE 21, EAST TO WEST, 9:28 AM

Photo Interpretation	Location/Time
inhomogeneous tone; striated parallel with FL; coarse texture; high and medium density in alternating rows (harvesting pattern); near total cover; furrows run parallel with FL.	FL 21/10B 9:28 AM 5/15/75 SURV II 17-34 25/1-4
East inhomogeneous tone; texture is differential with fine texture in unlodged areas and no texture in lodged areas; high density; total cover; most of the grain is lodged and furrows run parallel with FL. West inhomogeneous tone; texture is differential with no texture in lodged areas and fine texture in unlodged areas; high density; total cover; nonuniform differential ripening, areas of lodged grain; furrows run parallel with FL.	Fl 21/10A 9:28 AM 5/15/75 SURV II 41-72 25/2-5
inhomogeneous tone; fine texture; high density; near total cover; nonuniform differential ripening (high contrast); furrows run parallel with FL.	FL 21/11 9:28 AM 5/15/75 Surv II 76-90 25/5-9

Photo Interpretation	Location/Time
homogeneous tone; fine texture; low density; little cover; furrows run parallel with FL.	FL 21/13 9:28 AM 5/15/75 SURV II 96-112 25/7-10
homogeneous tone; medium texture; low density; little cover; field is divided into sections and division lines are void of crop cover; furrows run parallel with FL.	FL 21/112 9:28 AM 5/15/75 SURV II 116-128 25/10-13
inhomogeneous tone; fine texture; high density; total cover; nonuniform differential ripening; furrows run perpendicular to FL.	FL 21/111 9:28 AM 5/15/75 SURV II 113-148 25/11-15
inhomogeneous tone; fine texture; high density; total cover; nonuniform differential ripening; furrows run perpendicular to FL.	FL 21/109 9:28 AM 5/15/75 SURV II 152-166 25/14-17

Photo Interpretation	Location/Time
homogeneous tone except for slight furrow detection; fine texture; high density; total cover; furrows run parallel with FL.	FL 21/108 9:28 AM 5/15/75 SURV II 172-185 25/15-19
inhomogeneous tone; fine texture with the exception of bare soil areas; high density; total cover with the exception of two large bare soil areas on eastern boundary 65 feet wide running perpendicular to FL (previously a road curved through the field).	FL 21/100 9:28 AM 5/15/75 SURV II 191-204 25/18-20
homogeneous tone except for slight furrow detection; fine texture; high density; total cover (eastern border is sparse); furrows run parallel with FL.	FL 21/101 9:28 AM 5/15/75 SURV II 210-220 25/19-20
inhomogeneous tone; coarse texture; low density; little cover (differential growth); furrows run parallel with FL.	FL 21/34 9:28 AM 5/15/75 SURV II 236-260 25/22-25
homogeneous tone; no texture; high density; total cover.	FL 21/102 9:28 AM 5/15/75 SURV II 265-297 25/27-30

FLIGHT LINE 20, WEST TO EAST, 9:37 AM

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 20/103 9:37 AM 5/15/75 SURV II 328-359 7/4-6
inhomogeneous tone, striated perpendicular to FL; fine texture; low density; no cover; furrows run parallel with FL.	FL 20/34 9:37 AM 5/15/75 SURV II 363-385 7/6-9
inhomogeneous tone; coarse texture; differential density ranging nonuniformly from high to bare soil; 2/3 cover; furrows run perpendicular to FL.	FL 20/101 9:37 AM 5/15/75 SURV II 408-414 7/11-13
homogeneous tone except furrows are slightly detectable; texture is absent or fine; high density; total cover; furrows run parallel with FL.	FL 20/100 9:37 AM 5/15/75 SURV II 417-432 7/12-14

Photo Interpretation	Location/Time
homogeneous tone; fine texture; high density; total cover.	FL 20/108 9:37 AM 5/15/75 SURV II 438-451 7/13-16
inhomogeneous tone; texture is absent or fine; high density; total cover; nonuniform, differential ripening; furrows run perpendicular to FL	FL 20/109 9:37 AM 5/15/75 SURV II 455-469 7/15-18
homogeneous tone; no texture; high density; total cover.	FL 20/110 9:37 AM 5/15/75 SURV II 474-487 7/17-20
homogeneous tone; no texture; high density; total cover.	FL 20/37 9:37 AM 5/15/75 SURV II 494-523 7/19-22
homogeneous tone; medium texture; bare soil; furrows run parallel with FL.	FL 20/12 9:37 AM 5/15/75 SURV II 529-545 7/22-25

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture and areas of lodged grain have no texture; high density; total cover; nonuniform areas of distinctly riper grain and small scattered areas of lodged grain.	FL 20/10 9:37 AM 5/15/75 SURV II 552-575 7/25-28

FLIGHT LINE 19, EAST TO WEST, 9:43 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated parallel with FL; medium texture; bare soil; furrows running parallel with FL. (Scanning line runs only through northern half.)	FL 19/5 9:43 AM 5/15/75 SURV II 673-698 27/5-8
homogeneous tone except furrows are very slightly detectable; no texture; high density; total cover; furrows run perpendicular to FL.	FL 19/2 9:43 AM 5/15/75 SURV II 701-744 27/6-13
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 19/9 9:43 AM 5/15/75 SURV II 748-762 27/11-15

Photo Interpretation	Location/Time
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run perpendicular to FL.	FL 19/15 9:43 AM 5/15/75 SURV II 767-781 27/13-17
inhomogeneous tone, striated perpendicular to FL; coarse texture; alternating rows of medium and low density (harvesting pattern); 1/3 cover; furrows run perpendicular to FL.	FL 19/16 9:43 AM 5/15/75 SURV II 786-818 27/15-20
homogeneous tone; fine texture; high density; total cover; furrows run parallel with FL.	FL 19/107 9:43 AM 5/15/75 SURV II 824-856 27/19-24
homogeneous tone; no texture; high density; total cover.	FL 19/104 9:43 AM 5/15/75 SURV II 862-894 27/22-27

FLIGHT LINE 18, WEST TO EAST, 9:51 AM

Photo Interpretation	Location/Time
homogeneous tone with the exception of a grid of thin spots in what seems to be an irrigation pattern; texture is absent or fine; high density; near total cover; furrows run parallel with FL.	FL 18/106 9:51 AM 5/15/75 SURV II 966-997 15/6-10
homogeneous tone except furrows are detectable; fine texture; high density; near total cover with the exception of a few small sparse areas along western boundary; furrows run parallel with FL.	FL 18/17 9:51 AM 5/15/75 SURV II 1004-1018 15/9-12
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 18/18 9:51 AM 5/15/75 SURV II 1022-1034 15/11-14
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run perpendicular to FL.	FL 18/15 9:51 AM 5/15/75 SURV II 1041-1054 15/13-16

Photo Interpretation	Location/Time
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 18/9 9:51 AM 5/15/75 SURV II 1060-1073 15/15-18
inhomogeneous tone; coarse texture; low density; very little cover; what seems to be differential soil moisture and crop density is causing tonal pattern; furrows run parallel to FL.	FL 18/1 9:51 AM 5/15/75 SURV II 1079-1090 15/17-19
inhomogeneous tone; fine texture; high density; near total cover; differential ripening with the western 650 feet appearing less ripe; furrows run parallel with FL.	FL 18/3 9:51 AM 5/15/75 SURV II 1094-1117 15/18-23
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 18/4 9:51 AM 5/15/75 SURV II 1124-1149 15/21-24

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; low density; little cover; field has 2 rows of bare soil running perpendicular to FL which divide it into thirds; furrows run parallel with FL.	FL 18/4A 9:51 AM 5/15/75 SURV II 1159-1186 15/24-28

FLIGHT LINE 16, EAST TO WEST, 9:58 AM

Photo Interpretation	Location/Time
inhomogeneous tone; texture is differential with no texture in lodged areas and fine texture throughout the remaining field; high density; total cover; large areas of lodged grain; nonuniform ripening; furrows run perpendicular to FL.	FL 16/24 6:58 AM 5/15/75 SURV II 1223-1247 29/2-6
inhomogeneous tone; medium texture; high density; near total cover; western and eastern 650 feet are riper than center area; furrows run perpendicular to FL.	FL 16/23 9:58 AM 5/15/75 SURV II 1253-1286 29/4-10
inhomogeneous tone; medium texture; high density; near total cover; differential nonuniform ripening; furrows run perpendicular to FL.	FL 16/22 9:58 AM 5/15/75 SURV II 1290-1306 29/7-13
inhomogeneous tone; coarse texture; low density; little cover; nonuniform differential growth; furrows run perpendicular to FL.	FL 16/119 9:58 AM 5/15/75 SURV II 1329-1343 29/11-13

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; low density; little cover; eastern 520 feet have more dense cover; furrows run perpendicular to FL.	FL 16/14B 9:58 AM 5/15/75 SURV II 1348-1362 29/17-13
homogeneous tone; fine texture; high density; total cover.	FL 16/117-118 9:58 AM 5/15/75 SURV II 1367-1399 29/15-20
homogeneous tone except furrows are slightly detectable; texture is absent or fine; high density; total cover; furrows run parallel to FL.	FL 16/116 9:58 AM 5/15/75 SURV II 1405-1419 29/19-23
inhomogeneous tone; fine texture; high density; total cover; differential nonuniform ripening; furrows run parallel to FL.	FL 16/115 9:58 AM 5/15/75 SURV II 1424-1439 29/21-25

Photo Interpretation	Location/Time
homogeneous tone; fine texture; high density, however, slightly differential in rows; total cover; furrows run parallel with FL.	FL 16/114 9:58 AM 5/15/75 SURV II 1444-1456 29/23-27
inhomogeneous tone; texture is absent in lodged areas and fine in standing areas; high density; near total cover; large areas of lodged grain; furrows run parallel with FL.	FL 16/113 9:58 AM 5/15/75 SURV II 1462-1477 29/26-29

FLIGHT LINE 15, WEST TO EAST, 10:04 AM

Photo Interpretation	Location/Time
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 15/47 10:04 AM 5/15/75 SURV II 1518-1528 21/3-5
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 15/46 10:04 AM 5/15/75 SURV II 1533-1547 21/4-7
inhomogeneous tone; coarse texture; medium density; near total cover; furrows run perpendicular to FL.	FL 15/44 10:04 AM 5/15/75 SURV II 1553-1566 21/5-8
inhomogeneous tone, striated perpendicular to FL; medium texture; bare soil; furrows run perpendicular to FL.	FL 15/42 10:04 AM 5/15/75 SURV II 1570-1583 21/7-10

Photo Interpretation	Location/Time
homogeneous tone; fine texture; high density, total cover; field is uniformly ripe except grain in furrows is unripe; furrows run perpendicular to FL.	FL 15/40 10:04 AM 5/15/75 SURV II 1588-1620 21/9-14
inhomogeneous tone, striated perpendicular to FL; medium texture; high density; total cover; western 520 feet and eastern 390 feet are generally more ripe than the center 390 feet; differential ripening in alternating rows; furrows run perpendicular to FL.	FL 15/39 10:04 AM 5/15/75 SURV II 1624-1638 21/12-15
inhomogeneous tone, striated perpendicular to FL; coarse texture; differential density with alternating rows of high and low (harvesting pattern); 2/3 cover; nonuniform differential ripening and grain in furrows is unripe; furrows run perpendicular to FL.	FL 15/38 10:04 AM 5/15/75 SURV II 1643-1653 21/14-17
homogeneous tone; no texture; high density; total cover.	FL 15/25 10:04 AM 5/15/75 SURV II 1660-1691 21/16-17

Photo Interpretation	Location/Time
homogeneous tone; medium texture; medium density; near total cover.	FL 15/21 10:04 AM 5/15/75 SURV II 1697/1729 21/20-25
inhomogeneous tone; texture is absent or fine; high density; total cover; differential nonuniform ripening.	FL 15/36 10:04 AM 5/15/75 SURV II 1735-1764 21/24-28

FLIGHT LINE 14, EAST TO WEST, 10:10 AM

Photo Interpretation	Location/Time
3 cropping patterns--1) 1620 feet; 2) 590 feet; 3) 390 feet. 1) homogeneous tone; medium texture; medium density; near total cover; furrows run perpendicular to FL. 2) inhomogeneous tone; coarse texture; medium density; 2/3 cover; furrows run perpendicular to FL. 3) inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run perpendicular to FL.	FL 14/19 10:10 AM 5/15/75 SURV II 1805-1836 10/2-7
homogeneous tone; coarse texture; medium density; 2/3 cover; two 33 foot strips of higher density 390 feet and 590 feet from western border.	FL 14/20 10:10 AM 5/15/75 SURV II 1841-1872 10/5-10
inhomogeneous tone; coarse texture; low density; differential growth and cover with the eastern 390 feet and western 390 feet of higher density than the center 390 feet; field is divided into fourths by bare soil lines running perpendicular to FL; furrows run parallel with FL.	FL 14/35 10:10 AM 5/15/75 SURV II 1877-1907 10/8-14

Photo Interpretation	Location/Time
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel to FL.	Fl 14/46 10:10 AM 5/15/75 SURV II 2023-2037 10/23-27
homogeneous tone; medium texture; medium density; a few very small scattered areas of bare soil; near total cover; furrows run parallel with FL.	FL 14/47 10:10 AM 5/15/75 SURV II 2041-2055 10/25-29
inhomogeneous tone; nonuniform coarse texture; nonuniform differential densities ranging from high to medium; total cover; entire field is ripe; furrows run perpendicular to FL.	FL 14/47B 10:10 AM 5/15/75 SURV II 2077-2093 10/28-30
inhomogeneous tone; coarse texture; nonuniform differential densities ranging from high to medium; total cover; entire field is ripe; furrows run perpendicular to FL.	FL 14/47C 10:10 AM 5/15/75 SURV II 2098-2112 10/30-35

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture, nonuniform differential density ranging from high to medium; near total cover with a few scattered sparse areas; nonuniform differential ripening; furrows run perpendicular to FL.	FL 14/38 10:10 AM 5/15/75 SURV II 1913-1925 10/12-16
inhomogeneous tone; medium texture; high density; total cover; differential ripening in alternating rows; furrows run perpendicular to FL.	FL 14/39 10:10 AM 5/15/75 SURV II 1932-1945 10/14-18
homogeneous tone; medium texture; medium density; total cover.	FL 14/41 10:10 AM 5/15/75 SURV II 1950-1981 10/16-20
homogeneous tone but furrows are detectable and run perpendicular to FL; fine texture; bare soil; two very dark striations appear to be due to higher moisture content.	FL 14/43 10:10 AM 5/15/75 SURV II 1987-1998 10/19-23
inhomogeneous tone; coarse texture; differential density (alternating rows of medium and high density); 2/3 cover; furrows run perpendicular to FL.	FL 14/45 10:10 AM 5/15/75 SURV II 2003-2017 10/21-25

FLIGHT LINE 13, WEST TO EAST, 10:17 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated parallel with FL; coarse texture; medium density; near total cover; furrows run parallel with FL.	FL 13/120 10:17 AM 5/15/75 SURV II 2153-2183 19/3-6
8 cropping patterns--each 660 feet wide--all furrows run perpendicular to FL. 1) homogeneous tone; fine texture; medium density; total cover. 2) homogeneous tone, except furrows are detectable; fine texture; medium density; total cover; differential nonuniform ripening. 3) inhomogeneous tone; fine texture; medium density; nonuniform differential ripening. 4) inhomogeneous tone; coarse texture; low density; 1/3 cover. 5) inhomogeneous tone; coarse texture; low density; 1/3 cover. 6) inhomogeneous tone; coarse texture; low density; 1/3 cover. 7) homogeneous tone; fine texture; high density; total cover; nonuniform ripening. 8) inhomogeneous tone; coarse texture; low density; 1/3 cover.	FL 13/139 10:17 AM 5/15/75 SURV II 2224-2253 19/9-12
inhomogeneous tone; coarse texture; medium density; 2/3 cover; furrows run perpendicular to FL.	FL 13/124 10:17 AM 5/15/75 SURV II 2277-2289 19/14-17

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; differential densities in alternating rows of high, medium, and low (harvesting pattern); 1/3 cover; furrows run perpendicular to FL.	FL 13/48 10:17 AM 5/15/75 SURV II 2294-2324 19/16-20
homogeneous tone; no texture; high density; total cover.	FL 13/27 10:17 AM 5/15/75 SURV II 2328-2359 19/19-22
homogeneous tone except furrows are slightly detectable; texture is absent or fine; high density; total cover.	FL 13/26 10:17 AM 5/15/75 SURV II 2366-2395 19/23-27
inhomogeneous tone; fine texture; high density; total cover except irrigation furrows and a grid of small bare soil areas which seem to be an irrigation system pattern; furrows run parallel with FL.	FL 13/49 10:17 AM 5/15/75 SURV II 2400-2422 19/26-30

FLIGHT LINE 31, EAST TO WEST, 10:24 AM

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture; high density total cover; differential, nonuniform ripening (20 feet of western edge are especially ripe); furrows run parallel to FL.	FL 31/125 10:24 AM 5/15/75 SURV II 2444-2473 5/1-5
inhomogeneous tone; fine texture; nonuniform differential density ranging from high to medium; near total cover; furrows run perpendicular to FL.	FL 31/127 10:24 AM 5/15/75 SURV II 2478-2511 5/3-8
inhomogeneous tone striated perpendicular to FL; medium texture; differential densities ranging from high to low occurring in alternating rows (harvesting pattern); 2/3 cover; furrows run perpendicular to FL.	FL 31/129 10:24 AM 5/15/75 SURV II 2517-2547 5/6-12
inhomogeneous tone, striated perpendicular to FL; medium texture; differential density in alternating rows of high and medium (harvesting pattern); 2/3 cover; furrows run perpendicular to FL.	FL 31/134 10:24 AM 5/15/75 SURV II 2551-2566 5/11-14

Photo Interpretation	Location/Time
inhomogeneous tone, striated perpendicular to FL; medium texture; differential density in alternating rows of high and medium density (harvesting pattern); 2/3 cover; furrows run perpendicular to FL.	FL 31/133 10:24 AM 5/15/75 SURV II 2569-2584 5/12-15
inhomogeneous tone; medium texture; bare soil; three dark rows running perpendicular to FL may be due to soil moisture; furrows run perpendicular to FL.	FL 31/138 10:24 AM 5/15/75 SURV II 2607-2622 5/16-18
8 cropping patterns--each 660 feet wide--all furrows run perpendicular to FL. 1) homogeneous tone; fine texture; medium density; total cover. 2) homogeneous tone except furrows are detectable; fine texture; medium density; total cover. 3) inhomogeneous tone, fine texture, medium density; total cover; nonuniform differential ripening. 4) inhomogeneous tone; coarse texture; low density; 1/3 cover. 5) inhomogeneous tone; coarse texture; low density; 1/3 cover. 6) inhomogeneous tone; coarse texture; low density; 1/3 cover. 7) homogeneous tone; fine texture; high density; total cover; nonuniform differential ripening. 8) inhomogeneous tone; coarse texture; low density; 1/3 cover.	FL 31/139 10:24 AM 5/15/75 SURV II 2627-2655 5/18-22
homogeneous tone; fine texture; bare soil; furrows run parallel with FL.	FL 31/147 10:24 AM 5/15/75 2702-2733 5/25-30

FLIGHT LINE 30, WEST TO EAST, 10:30 AM

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture; density varies from medium to high with some sparse areas; near total cover; uniformly unripe; furrows run perpendicular to FL.	FL 30/145 10:30 AM 5/15/75 SURV II 2772-2787 6/2-3
homogeneous tone; medium texture; low density; little cover; furrows run perpendicular to FL.	FL 30/144 10:30 AM 5/15/75 SURV II 2790-2804 6/2-5
inhomogeneous tone; medium texture; medium density except for a bare soil area 65 feet wide 590 feet from western boundary; 2/3 cover; furrows run perpendicular to FL.	FL 30/143 10:30 AM 5/15/75 SURV II 2807-2839 6/4-8
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run perpendicular to FL.	FL 30/140 10:30 AM 5/15/75 SURV II 2843-2857 6/8-10

Photo Interpretation	Location/Tire
homogeneous tone; medium texture; medium density; near total cover; furrows run perpendicular to FL.	FL 30/141 10:30 AM 5/15/75 SURV II 2860-2875 6/10-12
inhomogeneous tone; fine texture; high density; total cover; nonuniform differential ripening.	FL 30/137 10:30 AM 5/15/75 SURV II 2878-2891 6/11-14
inhomogeneous tone; coarse texture; differential densities ranging from high to low occurring in alternating rows (harvesting pattern); near total cover; furrows run perpendicular to FL.	FL 30/135 10:30 AM 5/15/75 SURV II 2897-2910 6/13-16
inhomogeneous tone; medium texture; high density; near total cover; differential nonuniform ripening; furrows run perpendicular to FL.	FL 30/132 10:30 AM 5/15/75 SURV II 2916-2947 6/15-19

Photo Interpretation	Location/Time
4 cropping patterns--1) 390 feet, 2) 390 feet, 3) 260 feet, 4) 460 feet wide--all furrows run perpendicular to FL. 1) homogeneous tone; fine texture; bare soil. 2) inhomogeneous tone; coarse texture; medium density; 2/3 cover. 3) homogeneous tone; fine texture; bare soil. 4) inhomogeneous tone; coarse texture; medium density; 2/3 cover.	FL 30/131 10:30 AM 5/15/75 SURV II 2951-2964 6/19-21
inhomogeneous tone; coarse texture; density is differential ranging from high to low occurring in alternating rows; total cover; furrows run perpendicular to FL.	FL 30/130 10:30 AM 5/15/75 SURV II 2970-2984 6/21-23
3 cropping patterns--1) 590 feet, 2) 650 feet, 3) 1,240 feet wide. 1) homogeneous tone; medium texture; medium density; near total cover; furrows run perpendicular to FL. 2) inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run perpendicular to FL. 3) homogeneous tone; fine texture; high density; total cover.	FL 30/128 10:30 AM 5/15/75 SURV II 2991-3019 6/23-26
homogeneous tone; texture is absent or fine; high density except a line of sparse growth which is probalby a previous field boundary; total cover; furrows run perpendicular to FL.	FL 30/126 10:30 AM 5/15/75 SURV II 3024-3057 6/26-30

FLIGHT LINE 132 A, EAST TO WEST, 10:33 AM

Photo Interpretation	Location/Time
homogeneous tone; fine texture; high density; total cover; uniformly ripe; furrows run perpendicular to FL.	FL 132A/132A 10:33 AM 5/15/75 SURV II 3093-3127 6/33-36

FLIGHT LINE 21, EAST TO WEST, 10:42 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated parallel with FL; coarse texture; differential density ranging from high to low in alternating rows (harvesting pattern); near total cover; furrows run parallel with FL.	FL 21/10B 10:42 AM 5/15/75 SURV II 3147-3159 31/1-2
inhomogeneous tone; differential texture ranging from no texture in lodged areas to fine in unlodged areas; high density; total cover; much of the field is lodged; furrows run parallel with FL.	FL 21/10A 10:42 AM 5/15/75 SURV II 3167-3199 31/1-6
inhomogeneous tone; fine texture; high density; total cover; nonuniform differential ripening (high contrast); furrows run parallel with FL.	FL 21/11 10:42 AM 5/15/75 SURV II 3203-3217 31/4-8

Photo Interpretation	Location/Time
homogeneous tone; medium texture; bare soil; furrows run parallel with FL.	FL 21/13 10:42 AM 5/15/75 SURV II 3222-3237 31/6-10
homogeneous tone; medium texture; bare soil; furrows run parallel with FL.	FL 21/112 10:42 AM 5/15/75 SURV II 3242-3254 31/8-9
inhomogeneous tone; texture is absent or fine; high density; total cover; nonuniform differential ripening; furrows run perpendicular to FL.	FL 21/111 10:42 AM 5/15/75 SURV II 3258-3272 31/9-11
inhomogeneous tone; texture is absent or fine; high density; total cover; nonuniform differential ripening; furrows run perpendicular to FL.	FL 21/109 10:42 AM 5/15/75 SURV II 3276-3291 31/11-15

Photo Interpretation	Location/Time
homogeneous tone, except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 21/108 10:42 AM 5/15/75 SURV II 3295-3308 31/13-17
inhomogeneous tone; fine texture with the exception of bare soil areas on eastern boundary 65 feet wide running perpendicular to FL; high density; total cover with the exception of the bare soil areas (previously a road curved through the field).	FL 21/100 10:42 AM 5/15/75 SURV II 3313-3327 31/15-19
homogeneous tone except for slight furrow detection; fine texture; high density; total cover (eastern border is sparse); furrows run parallel with FL.	FL 21/101 10:42 AM 5/15/75 SURV II 3331-3342 31/16-20
inhomogeneous tone; coarse texture; low density; little cover; differential growth; furrows run parallel with FL.	FL 21/34 10:42 AM 5/15/75 SURV II 3357-3382 31/19-24
homogeneous tone; no texture; high density; total cover.	FL 21/102 10:42 AM 5/15/75 SURV II 3387-3411 31/22-28

FLIGHT LINE 220 SOUTH, WEST TO EAST, 11:35 AM

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; differential densities ranging from low in an area 330 feet wide located 130 feet from the western boundary, to alternating rows of high and low in the majority of the field; 2/3 cover; furrows run parallel with FL.	FL 220S/219 11:35 AM 9/23/75 SURV III 2069-2091 149/20-24
inhomogeneous tone; coarse texture; differential densities ranging from low in an area 330 feet wide located 130 feet from the western boundary, to alternating rows of high and low in the majority of the field; 2/3 cover; furrows run parallel with the FL.	FL 220S/220 11:35 AM 9/23/75 SURV III 2094-2108 149/28-30

FLIGHT LINE 21, EAST TO WEST, 11:42 AM

Photo Interpretation	Location/Time
no coverage	FL 21/10A 11:42 AM 9/23/75 SURV III
homogeneous tone; fine texture; bare soil.	FL 21/11 11:42 AM 9/23/75 SURV III 2139-2150 161/2-3
inhomogeneous tone; coarse texture; differential density, the western 330 feet are medium but the rest of the field is high; near total cover.	FL 21/13 11:42 AM 9/23/75 SURV III 2156-2171 161/3-5

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; differential density, the eastern 260 feet are medium, but the rest of the field is high; near total cover.	FL 21/112 11:42 AM 9/23/75 SURV III 2175-2184 161/5-6
homogeneous tone; fine texture; bare soil; furrows run perpendicular to FL.	FL 21/111 11:42 AM 9/23/75 SURV III 2188-2200 161/6-8
homogeneous tone; fine texture; bare soil; furrows run perpendicular to FL.	FL 21/109 11:42 AM 9/23/75 SURV III 2206-2219 161/6-10
homogeneous tone except furrows are distinguishable; fine texture; high density; total cover; furrows run parallel with FL.	FL 21/108 11:42 AM 9/23/75 SURV III 2225-2237 161/9-12

Photo Interpretation	Location/Time
inhomogeneous tone; differential texture ranging from fine for the majority of the field to coarse in the eastern 195 feet; differential density ranging from high for the majority of the field to low in the eastern 195 feet; near total cover; sparse eastern area caused by a road which previously curved through the field; furrows run parallel with the FL.	FL 21/100 11:42 AM 9/23/75 SURV III 2243-2257 161/11-13
inhomogeneous tone; nonuniform differential texture ranging from fine to coarse; nonuniform differential density ranging from medium to bare soil; 2/3 cover; furrows run parallel with FL.	FL 21/101 11:42 AM 9/23/75 SURV III 2261-2273 161/13-15
homogeneous tone; medium texture; low density, sparse growth near field edges but the majority of the field is bare soil; plowing configurations are detectable; furrows run parallel with the FL.	FL 21/34 11:42 AM 9/23/75 SURV III 2284-2308 161/15-19
homogeneous tone; medium texture; high density; total cover.	FL 21/102 11:42 AM 9/23/75 SURV III 2313-2343 161/18-22

FLIGHT LINE 3, WEST TO EAST, 9:54 AM

Photo Interpretation	Location/Time
homogeneous tone; fine texture; bare soil.	FL 3/214 & 215 9:54 AM 5/16/75 SURV II 3447-3489 22/2-7
homogeneous tone; medium texture; bare soil; furrows run parallel with FL.	FL 3/216 9:54 AM 5/16/75 SURV II 3493-3521 22/5-10
homogeneous tone; fine texture; high density; total cover; slight differential ripening; furrows run parallel with FL.	FL 3/217A 9:54 AM 5/16/75 SURV II 3531-3567 22/9-14
inhomogeneous tone; texture is differential and ranges from coarse to fine; density is differential and ranges from low to high with areas of bare soil; 2/3 cover; nonuniform differential ripening; furrows run parallel with FL.	FL 3/251 9:54 AM 5/16/75 SURV II 3571-3609 22/14-18

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 3/250 9:54 AM 5/16/75 SURV II 3613-3647 22/18-22
homogeneous tone except furrows are detectable and there is a 33 foot wide area of bare soil on the western border; fine texture; near total cover; furrows are parallel with FL.	FL 3/249 9:54 AM 5/16/75 SURV II 3652-3688 22/22-26
homogeneous tone; no texture; high density; total cover; uniformly unripe.	FL 3/247 9:54 AM 5/16/75 SURV II 3692-3731 22/26-29

FLIGHT LINE 2, WEST TO EAST, 10:03 AM

Photo Interpretation	Location/Time
inhomogeneous tone; texture gradates from west (coarse) to east (fine); density gradates from west (low) to east (medium); there is a bare soil area 330 feet wide in the western third of the field, however, the rest of the field has near total cover; nonuniform ripening; furrows run parallel with FL.	FL 2/219 10:03 AM 5/16/75 SURV II 3760-3787 17/2
inhomogeneous tone; texture gradates from west (coarse) to east (medium); density gradates from west (low) to east (medium); there is a large bare soil area in the western quarter, but the rest of the field has near total cover; western 260 feet are riper than the eastern 390 feet; furrows run parallel with the FL.	FL 2/220 10:03 AM 5/16/75 SURV II 3791-3808 17/3-7
homogeneous tone; no texture; high density; total cover; uniformly unripe.	FL 2/221 10:03 AM 5/16/75 SURV II 3813-3846 7/5-10
inhomogeneous tone; texture is differential and ranges from fine to medium; density is differential, ranging from medium to high with small areas of bare soil along what appears to be a previous field boundary; near total cover; furrows run parallel with the FL.	FL 2/223 10:03 AM 5/16/75 SURV II 3850-3885 17/9-14
inhomogeneous tone; coarse texture; density is differential ranging from low to medium with areas of bare soil; 2/3 cover; furrows run parallel with FL; diagonal pattern probably caused by subsurface drainage pipes producing diagonal striations of sparse cover.	FL 2/256 10:03 AM 5/16/75 SURV II 3890-3924 17/13-19

Photo Interpretation	Location/Time
inhomogeneous tone; texture is absent or fine; high density; total cover; nonuniform differential ripening; furrows run [illegible] FL.	FL 2/255 10:03 AM 5/16/75 SURV II 3929-3938 17/17-20
homogeneous tone except furrows are detectable; fine texture; high density; total cover; uniformly unripe; furrows run parallel with FL.	FL 2/254 10:03 AM 5/16/75 SURV II 3942-3965 17/18-22
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 2/257 10:03 AM 5/16/75 SURV II 3970-4005 17/21-26
homogeneous tone except furrows are slightly detectable; no texture; total cover; furrows run parallel with FL.	FL 2/253 10:03 AM 5/16/75 SURV II 4010-4026 17/25-28
inhomogeneous tone; medium texture; medium density; 2/3 cover; furrows run parallel with FL.	FL 2/252 10:03 AM 5/16/75 SURV II 4029-4046 17/27-29

FLIGHT LINE 1, WEST TO EAST, 10:08 AM

Photo Interpretation	Location/Time
inhomogeneous tone; nonuniform differential texture ranging from coarse to fine; high density with the exception of the western 460 feet which are sparse and patchy with areas of bare soil; near total cover; nonuniform differential ripening; furrows run parallel with FL.	FL 1/219 10:08 AM 5/16/75 SURV II 4075-4101 2/2-3
inhomogeneous tone; fine texture; high density; total cover; differential ripening with the western 460 feet riper than the rest of the field; furrows run parallel with the FL.	FL 1/220 10:08 AM 5/16/75 SURV II 4105-4119 2/5-7
homogeneous tone; no texture; high density; total cover.	FL 1/222 10:08 AM 5/16/75 SURV II 4123-4159 2/6-10
inhomogeneous tone; coarse texture; medium density; 2/3 cover; nonuniform differential ripening; furrows run parallel with FL.	FL 1/224 10:08 AM 5/16/75 SURV II 4164-4197 2/10-14

Photo Interpretation	Location/Time
inhomogeneous tone; nonuniform differential texture ranging from fine to coarse; non-uniform differential densities ranging from high to bare soil; nonuniform differential cover ranging from near total to bare soil; furrows run parallel with FL.	FL 1/256 10:08 AM 5/16/75 SURV II 4202-4234 2/14-18
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; slightly riper near western boundary; furrows run perpendicular to the FL.	FL 1/255 10:08 AM 5/16/75 SURV II 4238-4250 2/18-20
homogeneous tone except for very slight detection of furrows; texture is absent or fine; high density; total cover; furrows run parallel with FL.	FL 1/254 10:08 AM 5/16/75 SURV II 4255-4273 2/19-22
inhomogeneous tone; fine texture; medium density; 1/3 cover; nonuniform differential ripening; furrows run parallel with FL.	FL 1/257 10:08 AM 5/16/75 SURV II 4277-4311 2/22-26

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 1/253 10:08 AM 5/16/75 SURV II 4318-4335 2/25-28
inhomogeneous tone; coarse texture; medium density; 2/3 cover; furrows run parallel with FL.	FL 1/252 10:08 AM 5/16/75 SURV II 4339-4354 2/28-30

FLIGHT LINE 4, WEST TO EAST, 10:15 AM

Photo Interpretation	Location/Time
inhomogeneous tone striated parallel with FL; coarse texture; bare soil; furrows run parallel with FL.	FL 4/214 & 215 10:15 AM 5/16/75 SURV II 4382-4427 28/5-10
homogeneous tone; medium texture; bare soil; furrows run parallel with FL.	FL 4/216 10:15 AM 5/16/75 SURV II 4432-4465 28/5-10
homogeneous tone; fine texture; low density; little cover; furrows run parallel with FL.	FL 4/217 10:15 AM 5/16/75 SURV II 4470-4503 28/9-14
inhomogeneous tone; fine texture; high density; total cover; differential ripening in a diagonal pattern probably caused by subsurface drainage pipes.	FL 4/251 10:15 AM 5/16/75 SURV II 4508-4547 28/13-17

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 4/250 10:15 AM 5/16/75 SURV II 4552-4583 28/18-20
homogeneous tone; no texture; high density; total cover.	FL 4/248 10:15 AM 5/16/75 SURV II 4589-4623 28/20-25
homogeneous tone; no texture; high density; total cover.	FL 4/247 10:15 AM 5/16/75 4628-4666 28/24-29

FLIGHT LINE 5, WEST TO EAST, 10:20 AM

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 5/200 10:20 AM 5/16/75 SURV II 4707-4726 8/3-6
inhomogeneous tone; differential texture with most of the field fine but scattered areas of medium and coarse; high density with the exception of sparse areas along what appears to be a previous field boundary, and a grid of spots of bare soil in what seems to be an irrigation pattern; uniformly unripe; furrows run parallel with FL.	FL 5/201 10:20 AM 5/16/75 SURV II 4730-4751 8/5-9
inhomogeneous tone; texture is absent or fine, with the exception of coarse texture in an area of bare soil; sparse cover; high density with the exception of a curvilinear, 65 foot wide 990 foot long area of bare soil running parallel with FL; uniformly unripe; furrows run parallel with FL.	FL 5/202 10:20 AM 5/16/75 SURV II 4755-4777 8/8-10

Photo Interpretation	Location/Time
homogeneous tone; fine texture; high density; total cover with the exception of a curvilinear area of bare soil 33 feet wide and 990 feet long parallel with the FL, extending from the eastern boundary.	FL 5/203 10:20 AM 5/16/75 SURV II 4782-4804 8/11-14
inhomogeneous tone; texture is absent or fine; low density; little cover; furrows run parallel with FL; differential soil moisture causing tonal patterns.	FL 5/204 10:20 AM 5/16/75 SURV II 4809-4832 8/13-17
homogeneous with a slight detection of furrows; fine texture; high density; total cover; furrows run parallel with FL.	FL 5/244 10:20 AM 5/16/75 SURV II 4837-4860 8/16-19
inhomogeneous tone; fine texture; high density; total cover, differential nonuniform ripening.	FL 5/243 10:20 AM 5/16/75 SURV II 4864-4888 8/19-22

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; low density; 1/3 cover; field divided with a dark moist area 65 feet wide along division; furrows parallel with FL.	FL 5/242 10:20 AM 5/16/75 SURV II 4892-4909 8/22-24
inhomogeneous tone; differential texture--western 330 feet are medium texture and the rest of the field has either fine or no texture; high density with exception of western 1300 feet (medium); near total cover; furrows run parallel with the FL.	FL 5/241 10:20 AM 5/16/75 SURV II 4913-4947 8/24-28
inhomogeneous tone; fine texture; high density; total cover; nonuniform ripening, field edges and western 390 feet are noticeably more ripe.	FL 5/240 10:20 AM 5/16/75 SURV II 4953-4991 8/28-33

FLIGHT LINE 6, WEST TO EAST, 10:27 AM

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 6/200 10:27 AM 5/16/75 SURV II 5034-5055 13/3-7
homogeneous tone with the exception of a spot of bare soil (65 feet diameter) near the western boundary and a few small spots of bare soil in what seems to be an irrigation pattern; texture is either absent or fine and coarse around the bare soil area; high density with the exception of the bare soil area; near total cover; uniformly unripe; furrows run parallel with FL.	FL 5/201 10:27 AM 5/16/75 SURV II 5060-5079 13/5-9
homogeneous tone; texture is absent or fine, becoming medium at field edges; high density; uniformly unripe; furrows run parallel with FL.	FL 6/202 10:27 AM 5/16/75 SURV II 5083-5107 13/8-12

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture; high density; total cover; nonuniform differential ripening except the western 650 feet are uniformly more ripe.	FL 6/203 10:27 AM 5/16/75 SURV II 5111-5134 13/11-15
inhomogeneous tone; fine texture; low density; very slight cover; furrows run parallel with FL; differential soil moisture pattern.	FL 6/204 10:27 AM 5/16/75 SURV II 5137-5158 13/13-17
inhomogeneous tone with a grid of spots of bare soil which seem to be an irrigation pattern; texture is differential and ranges from fine to medium to high; furrows run parallel with FL.	FL 6/244 10:27 AM 5/16/75 SURV II 5162-5185 13/16-20
inhomogeneous tone; texture is differential, ranging from fine to medium; medium density; near total cover; differential ripening with the western 330 feet riper than the rest of the field; furrows run parallel with FL.	FL 6/243 10:27 AM 5/16/75 SURV II 5190-5214 13/19-22

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; low density; 1/3 cover and field is divided into quadrants by lines of bare soil; furrows run parallel with FL.	FL 6/242 10:27 AM 5/16/75 SURV II 5218-5233 13/21-24
homogeneous tone; no texture; high density; total cover.	FL 6/241 10:27 AM 5/16/75 SURV II 5238-5272 13/23-28
inhomogeneous tone; fine texture; high density; total cover; differential ripening in diagonal line pattern probably caused by subsurface drainage pipes.	FL 6/240 10:27 AM 5/16/75 SURV II 5277-5311 13/27-31

FLIGHT LINE 7, WEST TO EAST, 10:34 AM

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture; high density, the western 130 feet are medium density; near total cover; slight nonuniform, differential ripening; furrows run parallel with FL.	FL 7/209 10:34 AM 5/16/75 SURV II 5344-5363 3/1-4
inhomogeneous tone; coarse texture; low density; little cover; furrows run parallel with FL.	FL 7/211 10:34 AM 5/16/75 SURV II 5366-5420 3/3-9
inhomogeneous tone; medium texture; high density, however, a curvilinear area of bare soil 33 feet wide runs across the entire field; near total cover; furrows run parallel with FL.	FL 7/212 10:34 AM 5/16/75 SURV II 5425-5451 3/9-13
homogeneous tone with the exception of the irrigation furrows and a bare soil area 330 feet long and 65 feet wide on the western edge of the field; medium texture; high density with the exception of the bare soil area; furrows run parallel with FL.	FL 7/213 10:34 AM 5/16/75 SURV II 5456-5480 3/12-16

Photo Interpretation	Location/Time
homogeneous tone except irrigation furrows are slightly detectable; fine texture; high density; total cover; irrigation furrows run parallel with FL.	FL 7/237 10:34 AM 5/16/75 SURV II 5485-5515 3/15-19
inhomogeneous tone; texture is differential ranging from medium to coarse; density is differential ranging from medium to low; crop cover is in a diagonal pattern, probably caused by subsurface drainage pipes producing striations of sparse cover; furrows run parallel with FL.	FL 7/236 10:34 AM 5/16/75 SURV II 5519-5556 3/18-23
homogeneous tone; no texture, with the exception of 65 feet of coarse texture on the western edge; high density except western field edge; near total cover; furrows run parallel with FL.	FL 7/235 10:34 AM 5/16/75 SURV II 5561-5599 3/23-28
homogeneous tone; no texture; high density; total cover.	FL 7/234A 10:34 AM 5/16/75 SURV II 5603-5620 3/27-30

Photo Interpretation	Location/Time
inhomogeneous tone, striated parallel with FL; coarse texture; differential density ranging from low to high in alternating rows (harvesting pattern); 2/3 cover; furrows run parallel with FL.	FL 7/234B 10:34 AM 5/16/75 SURV II 5624-5635 3/29-32

FLIGHT LINE 8, WEST TO EAST, 10:40 AM

Photo Interpretation	Location/Time
inhomogeneous tone; nonuniform differential texture ranging from medium to fine; non-uniform differential density ranging from high to medium; near total cover; nonuniform differential ripening; furrows run parallel with FL.	FL 8/209 10:40 AM 5/16/75 SURV II 5670-5710 36/2-6
inhomogeneous tone; texture is differential and ranges from fine to medium; high density but there are nonuniform areas of medium density; near total cover; field is divided by a line of bare soil which was probably a previous field boundary; furrows run parallel with FL.	FL 8/210 10:40 AM 5/16/75 SURV II 5714-5751 36/6-10
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 8/212 10:40 AM 5/16/75 SURV II 5756-5783 36/10-14
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 8/213 10:40 AM 5/16/75 SURV II 5787-5812 36/13-17

Photo Interpretation	Location/Time
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 8/237 10:40 AM 5/16/75 SURV II 5816-5848 36/16-20
inhomogeneous tone; coarse texture; low density; 1/3 cover; diagonal pattern to crop cover, probably caused by subsurface drainage pipes, producing diagonal striations of sparse cover; furrows run parallel with FL.	FL 8/236 10:40 AM 5/16/75 SURV II 5853-5892 36/19-25
homogeneous tone, except furrows are slightly dectectable; texture is absent or fine; high density; total cover; furrows run parallel with FL.	FL 8/235 10:40 AM 5/16/75 SURV II 5898-5936 36/24-29
homogeneous tone; fine texture; high density; total cover.	FL 8/234A 10:40 AM 5/16/75 SURV II 5941-5959 36/28-32
inhomogeneous tone; striated parallel with FL; coarse texture; differential densities ranging from high to low in alternating rows (harvesting pattern); 2/3 cover; furrows run parallel with FL.	FL 8/234B 10:40 AM 5/16/75 SURV II 5964-5983 36/30-33

FLIGHT LINE 9, WEST TO EAST; 10:47 AM

Photo Interpretation	Location/Time
inhomogeneous tone; texture is differential ranging from medium for the majority of the field to coarse in a 195 foot wide strip 200 feet from western border; medium density; near total cover except western 195 foot area is sparse; furrows run parallel to FL.	FL 9/205 10:47 AM 5/16/75 SURV II 6011-6054 24/2-7
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 9/206 10:47 AM 5/16/75 SURV II 6059-6093 24/7-11
homogeneous tone; medium texture; differential densities ranging from medium to high in alternating rows; total cover; furrows run parallel with FL.	FL 9/207 10:47 AM 5/16/75 SURV II 6097-6130 24/11-15
inhomogeneous tone; high density; total cover; field becomes uniformly more ripe westward and grain in furrows remains unripe; furrows run parallel with FL.	FL 9/208 10:47 AM 5/16/75 SURV II 6135-6159 24/15-18

Photo Interpretation	Location/Time
inhomogeneous tone striated parallel to FL; coarse texture; medium density; 2/3 cover; furrows run parallel with FL.	FL 9/225 10:47 AM 5/16/75 SURV II 6165-6189 24/18-21
inhomogeneous tone; coarse texture; density is differential with alternating rows of high and low (harvesting pattern); 1/3 cover; furrows run parallel to FL.	FL 9/226 10:47 AM 5/16/75 SURV II 6193-6226 24/20-25
inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run parallel with FL; field is divided into quadrants, the eastern quadrants have a darker signature while the western quadrants are lighter probably due to soil moisture difference.	FL 9/227A 10:47 AM 5/16/75 SURV II 6232-6266 24/24-29
inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run parallel to FL; a line of bare soil (previous field boundary) divides the field into north and south and the cover is also sparse along the eastern and western edges of the field.	FL 9/228 10:47 AM 5/16/75 SURV II 6273-6287 24/28-31

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture in areas of higher growth, medium in areas where the crop is lower to the ground; low density; nonuniform cover; furrows run parallel with FL.	FL 9/229 10:47 AM 5/16/75 SURV II 6296-6307 24/30-33

FLIGHT LINE 10, WEST TO EAST, 10:55 AM

Photo Interpretation	Location/Time
homogeneous tone; medium texture; medium density; near total cover.	FL 10/205 10:55 AM 5/16/75 SURV II 6322-6366 30/1-7
homogeneous tone except furrows are detectable; fine texture; high density except an area 330 feet long which is slightly more sparse; near total cover; furrows run parallel with the FL.	FL 10/206 10:55 AM 5/16/75 SURV II 6373-6407 30/4-10
homogeneous tone; medium texture; slightly differential density ranging from medium to high in alternating rows; total cover; furrows run parallel with FL.	FL 10/207 10:55 AM 5/16/75 SURV II 6411-6445 30/9-14
homogeneous tone; fine texture; high density; total cover; field is ripening uniformly; furrows run parallel with FL.	FL 10/208 10:55 AM 5/16/75 SURV II 6450-6483 30/13-17

Photo Interpretation	Location/Time
inhomogeneous tone, striated parallel with FL; coarse texture; differential density, low and high in alternating rows (harvesting pattern); furrows run parallel with FL.	FL 10/225 10:55 AM 5/16/75 SURV II 6488-6499 30/16-20
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 10/226 10:55 AM 5/16/75 SURV II 6505-6537 30/18-24
homogeneous tone except furrows are slightly detectable; texture is absent or fine; high density; total cover; furrows run parallel with FL.	FL 10/227 10:55 AM 5/16/75 SURV II 6542-6576 30/22-28
inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run parallel with FL; crop cover is in a diagonal pattern, probably because of subsurface drainage pipes producing diagonal striations of sparse cover.	FL 10/228 10:55 AM 5/16/75 SURV II 6582-6596 30/25-30

Photo Interpretation	Location/Time
inhomogeneous tone; medium texture; low density; 1/3 cover; signs of differential soil moisture (65 foot wide strips perpendicular to FL which are darker than the rest of the field); furrows run parallel with FL.	FL 10/229 10:55 AM 5/16/75 SURV II 6601-6615 30/28-31

FLIGHT LINE 3, WEST TO EAST, 11:03 AM

Photo Interpretation	Location/Time
inhomogeneous tone; fine texture; bare soil; field is divided into north and south parallel with FL; the northern half is dry with a light signature; the southern half is wet with a dark signature; furrows run parallel with the FL.	FL 3/214 &215 11:03 AM 5/16/75 SURV II 6640-6674 37/1-7
homogeneous tone; fine texture; bare soil.	FL 3/216 11:03 AM 5/16/75 SURV II 6678-6717 37/6-10
homogeneous tone; fine texture; high density; total cover; slight nonuniform differential ripening.	FL 3/217A 11:03 AM 5/16/75 SURV II 6726-6760 37/10-14
inhomogeneous tone; differential texture ranging from fine in the majority of the field to coarse in the bare soil area; differential density ranging from high for the majority of the field to bare soil; 2/3 cover, a curvilinear area of bare soil 65 feet wide runs parallel with the FL for 650 feet; differential ripening occurs in diagonal striations probably caused by subsurface drainage pipes; furrows run parallel with the FL.	FL 3/251 11:03 AM 5/16/75 SURV II 6764-6806 37/14-19

Photo Interpretation	Location/Time
homogeneous tone; no texture; high density; total cover.	FL 3/250 11:03 AM 5/16/75 SURV II 6810-6844 37/18-23
homogeneous tone except furrows are detectable; fine texture; high density; near total cover; field is subdivided into quarter-mile halves; furrows run parallel with FL.	FL 3/249 11:03 AM 5/16/75 SURV II 6849-6884 37/22-27
homogeneous tone; no texture; high density; total cover.	FL 3/247 11:03 AM 5/15/75 SURV II 6889-6924 37/26-31

FLIGHT LINE C-538, EAST TO WEST, 10:55 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated perpendicular to FL; coarse texture; differential density ranging from bare soil to low to high density in alternating rows (harvesting pattern) with the exception of a large bare soil area; 2/3 cover with the exception of a bare soil area 195 feet wide near the western boundary; entire field is ripe; furrows run perpendicular to FL.	FL C-538/C-538 10:55 AM 5/20/75 SURV II 7038-7086 112/4-11

FLIGHT LINE 47, EAST TO WEST, 11:15 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated perpendicular to FL; coarse texture; differential density ranging from bare soil to low to high density in alternating rows (harvesting pattern); 2/3 cover; entire field is ripe; furrows run perpendicular to FL.	FL 47/47B 11:15 AM 5/20/75 SURV II 7126/7156 114/3-7
inhomogeneous tone, striated perpendicular to FL; differential density ranging from bare soil to low to high density in alternating rows (harvesting pattern); 2/3 cover; entire field is ripe; furrows run perpendicular to FL.	FL 47/47C 11:15 AM 5/20/75 SURV II 7162-7184 114/5-9
homogeneous tone; fine texture; bare soil.	FL 47/47D 11:15 AM 5/20/75 SURV II 7187-7206 114/8-12

FLIGHT LINE 21, EAST TO WEST, 10:26 AM

Photo Interpretation	Location/Time
homogeneous tone; medium texture; bare soil; furrows run perpendicular to FL.	FL 21/10A 10:26 AM 9/23/75 SURV II 7242-7257 158/2-3
homogeneous tone; fine texture; bare soil; furrows run perpendicular to FL.	FL 21/11 10:26 AM 9/23/75 SURV II 7264-7273 158/3-5
inhomogeneous tone; coarse texture; differential density ranging from bare soil to high, the western 650 feet tend to be more sparse; near total cover; furrows run parallel with FL.	FL 21/13 10:26 AM 9/23/75 SURV II 7280-7293 158/5-7

Photo Interpretation	Location/Time
homogeneous tone; coarse texture; high density; total cover; furrows run parallel with FL.	FL 21/112 10:26 AM 9/23/75 SURV II 7298-7308 158/6-9
homogeneous tone; medium texture; bare soil; furrows run perpendicular to FL.	FL 21/111 10:26 AM 9/23/75 SURV II 7313-7323 158/8-10
homogeneous tone; medium texture; bare soil; furrows run perpendicular to FL.	FL 21/109 10:26 AM 9/23/75 SURV II 7328-7341 158/10-11
inhomogeneous tone; medium texture; density is high with the exception of scattered small sparse areas and a large sparse area, 195 feet wide off the eastern boundary; near total cover; furrows run parallel with FL.	FL 21/108 10:26 AM 9/23/75 SURV II 7347-7360 158/11-13

Photo Interpretation	Location/Time
inhomogeneous tone; medium texture; differential nonuniform densities ranging from low to medium; 2/3 cover; furrows run parallel with FL.	FL 21/100 10:26 AM 9/23/75 SURV II 7364-7378 158/15-17
inhomogeneous tone; medium texture; high density; near total cover with the exception of some areas of sparse cover on the eastern boundary; furrows run parallel with FL.	FL 21/102 10:26 AM 9/23/75 SURV II 7430-7456 158/20-24
inhomogeneous tone; medium texture; low density; little cover; differential nonuniform growth; furrows run parallel with FL.	FL 21/34 10:26 AM 9/23/75 SURV II 7404-7426 158/17-21
homogeneous tone; coarse texture; bare soil; furrows run parallel with flight line.	FL 21/101 10:26 AM 9/23/75 SURV II 7382-7391 158/13-15

FLIGHT LINE 20, EAST TO WEST, 10:32 AM

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; bare soil; furrows run parallel with FL.	FL 20/10 10:32 AM 9/23/75 SURV II 7486-7500 153/2-3
homogeneous tone except furrows are detectable; coarse texture; high density; total cover; furrows run parallel with FL.	FL 20/12 10:32 AM 9/23/75 SURV II 7506-7521 153/3-5
inhomogeneous tone; coarse texture; differential nonuniform density ranging from low to medium; 2/3 cover; furrows run perpendicular to FL.	FL 20/37 10:32 AM 9/23/75 SURV II 7526-7553 153/5-8
inhomogeneous tone; differential nonuniform texture ranging from medium to coarse; differential nonuniform density ranging from low to medium; near total cover; furrows run perpendicular to FL.	FL 20/110 10:32 AM 9/23/75 SURV II 7558-7570 153/8-10
homogeneous tone; medium texture; bare soil; furrows run perpendicular to FL.	FL 20/109 10:32 AM 9/23/75 SURV II 7575-7586 153/10-12

Photo Interpretation	Location/Time
homogeneous tone, except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 20/108 10:32 AM 9/23/75 SURV II 7590-7604 153/12-14
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 20/100 10:32 AM 9/23/75 SURV II 7608-7621 153/13-15
inhomogeneous tone, striated perpendicular to FL; coarse texture; differential density ranging from bare soil to low to medium and this pattern tends to exist in alternating rows; 1/3 cover; furrows run perpendicular to FL.	FL 20/101 10:32 AM 9/23/75 SURV II 7624-7631 153/15-16
homogeneous tone; fine texture; bare soil except there are small thinly distributed areas of growth; furrows run parallel with FL.	FL 20/34 10:32 AM 9/23/75 SURV II 7650-7671 153/17-20
homogeneous tone; medium texture; high density; total cover.	FL 20/103 10:32 AM 9/23/75 SURV II 7676-7705 153/20-24

FLIGHT LINE 19, EAST TO WEST, 10:37 AM

Photo Interpretation	Location/Time
inhomogeneous tone; coarse texture; differential density, the majority of the field is high with the exception of a sparse area 330 feet wide near the center of the field; near total cover; furrows run parallel with the FL.	FL 19/5 10:37 AM 9/23/75 SURV II 7742-7774 156/3-5
inhomogeneous tone; coarse texture; nonuniform differential densities ranging from low to high; 2/3 cover; furrows run perpendicular to FL.	FL 19/2 10:37 AM 9/23/75 SURV II 7778-7809 156/5-9
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 19/9 10:37 AM 9/23/75 SURV II 7814-7826 156/9-11
homogeneous tone except furrows are slightly detectable; high density; total cover; furrows run perpendicular to FL.	FL 19/15 10:37 AM 9/23/75 SURV II 7831-7844 156/11-13

Photo Interpretation	Location/Time
2 cropping patterns--1) 1,495 feet, 2) 1,495 feet. 1) inhomogeneous tone; coarse texture; medium density; 2/3 cover; furrows run perpendicular to FL. 2) inhomogeneous tone; coarse texture; low density; 1/3 cover; furrows run perpendicular to FL.	FL 19/16 10:37 AM 9/23/75 SURV II 7849-7879 156/13-17
homogeneous tone; fine texture; bare soil.	FL 19/107 10:37 AM 9/23/75 SURV II 7884-7914 156/17-20
homogeneous tone; medium texture; high density; total cover.	FL 19/104 10:37 AM 9/23/75 SURV II 7919-7946 156/20-24

FLIGHT LINE 18, EAST TO WEST , 10:44 AM

Photo Interpretation	Location/Time
inhomogeneous tone; medium texture; bare soil; tonal patterns caused by differential soil moisture.	FL 18/4 10:44 AM 9/23/75 SURV II 7974-7992 152/2-3
inhomogeneous tone; medium texture; bare soil; tonal patterns caused by differential soil moisture.	FL 18/3 10:44 AM 9/23/75 SURV II 7995-8017 152/3-6
homogeneous tone; fine texture; bare soil; plowing patterns are detectable.	FL 18/1 10:44 AM 9/23/75 SURV II 8020-8033 152/5-8
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 18/9 10:44 AM 9/23/75 SURV II 8038-8052 152/7-9

Photo Interpretation	Location/Time
homogeneous tone except furrows are detectable; medium texture; high density; total cover; furrows run perpendicular to FL.	FL 18/15 10:44 AM 9/23/75 SURV II 8057-8070 152/9-11
homogeneous tone except furrows are detectable; fine texture; high density; total cover; furrows run parallel with FL.	FL 18/18 10:44 AM 9/23/75 SURV II 8075-8088 152/11-13
homogeneous tone; fine texture; high density; total cover; 98 foot area off western boundary is less dense; furrows run parallel with FL.	FL 18/17 10:44 AM 9/23/75 SURV II 8091-8105 152/12-15
homogeneous tone; fine texture; bare soil.	FL 18/106 10:44 AM 9/23/75 SURV II 8110-8140 152/14-18

FLIGHT LINE 401 SOUTH, WEST TO EAST, 10:48 AM

Photo Interpretation	Location/Time
2 cropping patterns--1) 910 feet, 2) 1,630 feet wide--all furrows run perpendicular to FL. 1) inhomogeneous tone, striated perpendicular to FL; medium texture; differential densities ranging from bare soil to low to medium in alternating rows (harvesting pattern); 1/3 cover. 2) homogeneous tone; fine texture; medium density; near total cover.	FL 401S/401 10:48 AM 9/23/75 SURV II 8202-8237 152/24-28

FLIGHT LINE 401 NORTH, EAST TO WEST, 10:51 AM

Photo Interpretation	Location/Time
2 cropping patterns--1) 910 feet, 2) 1,630 feet wide--all furrows run perpendicular to FL. 1) inhomogeneous tone, striated perpendicular to FL; medium texture; differential densities ranging from bare soil to low to medium in alternating rows (harvesting pattern); 1/3 cover. 2) homogeneous tone; fine texture; medium density; near total cover.	FL 401N/401 10:51 AM 9/23/75 SURV II 8262-8290 152/29-30

FLIGHT LINE 147-121, WEST TO EAST, 10:56 AM

Photo Interpretation	Location/Time
homogeneous tone for the eastern 3,690 feet but inhomogeneous tone for the western 680 feet; coarse texture; high density for the eastern side of the field and medium density for the western; total cover for the eastern side of the field and 2/3 cover for the western; furrows run parallel with the FL.	FL 147-121/147 10:56 AM 9/23/75 SURV II 8318-8354 154/2-6
inhomogeneous tone; coarse texture; nonuniform differential density ranging from low to medium; 1/3 cover; furrows run perpendicular to FL.	FL 147-121/121 10:56 AM 9/23/75 SURV II 8360-8374 154/5-9

FLIGHT LINE 143-121, NORTH TO SOUTH, 10:59 AM

Photo Interpretation	Location/Time
inhomogeneous tone; differential texture, the northern 845 feet have coarse texture while the southern 650 feet have medium texture; differential density, the northern section is predominantly bare soil with nonuniform patches of medium density crop cover while the southern section is medium density; little cover in northern section but near total cover in the southern section; furrows run perpendicular to FL.	FL 143-121/143 10:59 AM 9/23/75 SURV II 8395-8408 154/10-11
inhomogeneous tone; coarse texture; nonuniform differential density ranging from bare soil to medium; 2/3 cover; furrows run perpendicular to FL.	FL 143-121/121 10:59 AM 9/23/75 SURV II 8413-8442 154/11-14

FLIGHT LINE 143, EAST TO WEST, 11:03 AM

Photo Interpretation	Location/Time
homogeneous tone; medium texture; medium density; near total cover; furrows run perpendicular to FL.	FL 143/143 11:03 AM 9/23/75 SURV II 8469-8502 154/16-20

FLIGHT LINE 402, WEST TO EAST, 11:07 AM

Photo Interpretation	Location/Time
homogeneous tone except furrows are slightly detectable; fine texture; high density; total cover; furrows run perpendicular to FL.	FL 402/402 11:07 AM 9/23/75 SURV II 8526-8563 154/21-25

FLIGHT LINE 403, NORTH TO SOUTH, 11:14 AM

Photo Interpretation	Location/Time
inhomogeneous tone, striated perpendicular to FL; coarse texture; differential density ranging from bare soil to medium in alternating rows (harvesting pattern); 1/3 cover; furrows run perpendicular to FL.	FL 403/403 11:14 AM 9/23/75 SURV II 8592-8627 154/29-33

FLIGHT LINE 4, WEST TO EAST, 11:19 AM

Photo Interpretation	Location/Time
homogeneous tone except furrows are slightly detectable; coarse texture; high density; total cover; furrows run parallel with FL.	FL 4/406 11:19 AM 9/23/75 SURV II 8653-8675 169/2-4
homogeneous tone; medium texture; high density; total cover except for a few small scattered sparse areas; furrows run parallel with FL.	FL 4/214 & 215 11:19 AM 9/23/75 SURV II 8682-8762 160/4-7
homogeneous tone; medium texture; high density; total cover; furrows run parallel with FL.	FL 4/216 11:19 AM 9/23/75 SURV II 8766-8799 160/7-9
homogeneous tone; medium texture; high density; total cover; furrows run parallel with FL.	FL 4/217 11:19 AM 9/23/75 SURV II 8803-8841 160/12-17

FLIGHT LINE 405-404, WEST TO EAST, 11:22 AM

Photo Interpretation	Location/Time
3 cropping patterns--1) 650 feet, 2) 990 feet, 3) 1,495 feet wide--all furrows run perpendicular to FL. 1) inhomogeneous tone; medium texture; low density; 1/3 cover. 2) inhomogeneous tone; medium texture; low density; little cover; nonuniform differential growth. 3) inhomogeneous tone; fine texture; low density and bare soil; little cover and bare soil; nonuniform differential growth.	FL 405/405 11:22 AM 9/23/75 SURV II 8873-8906 160/23-27
2 cropping patterns--1) 1,300 feet, 2) 1,300 feet wide--all furrows run parallel with FL. 1) homogeneous tone; medium texture; high density; total cover. 2) inhomogeneous tone; coarse texture; nonuniform differential density ranging from bare soil to high; 2/3 cover.	FL 405/404 11:22 AM 9/23/75 SURV II 8911-8947 160/26-31

FLIGHT LINE 255-254, WEST TO EAST, 11:26 AM

Photo Interpretation	Location/Time
homogeneous tone except furrows are detectable; medium texture; high density; total cover; furrows run perpendicular to FL.	FL 255-254/255 11:26 AM 9/23/75 SURV II 1739-1748 160/32-35
inhomogeneous tone; medium texture; nonuniform differential density ranging from low to medium; 2/3 cover; furrows run parallel with FL.	FL 255-254/254 11:26 AM 9/23/75 SURV III 1751-1766 160/32-35

FLIGHT LINE 3, WEST TO EAST, 11:30 AM

Photo Interpretation	Location/Time
homogeneous tone; medium texture; high density; total cover.	FL 3/214 & 215 11:30 AM 9/23/75 SURV II 1829-1867 149/2-6
homogeneous tone; medium texture; high density; total cover.	FL 3/216 11:30 AM 9/23/75 SURV II 1871-1893 149/6-9
inhomogeneous tone; medium texture; nonuniform differential densities ranging from medium to high; near total cover; furrows run parallel with FL.	FL 3/217A 11:30 AM 9/23/75 SURV II 1901-1933 149/9-13
inhomogeneous tone; medium texture; medium density; field is ripening in diagonal striations probably caused by subsurface drainage pipes; furrows run parallel with FL.	FL 3/251 11:30 AM 9/23/75 SURV III 1938-1973 149/13-17

(77-121)

GROUND TRUTH MANAGEMENT SYSTEM TO SUPPORT MULTISPECTRAL SCANNER (MSS) DIGITAL ANALYSIS

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BIOGRAPHICAL SKETCH

Jerry C. Coiner is Senior Research Associate and Lecturer in Geography at Columbia University. His research interests are application of remote sensed data to monitoring social and environmental change. Coiner received his B.A., M.A. and Ph.D. from the University of Kansas. He is co-principal investigator on a NASA grant entitled "Application of Digital Analysis of MSS Data to Agro-Environmental Studies" as well as a consultant to the United Nations, Centre for Housing, Building and Development, for applications of information systems to the physical planning process.

Stephen G. Ungar heads the Earth Resources Program at NASA, Goddard Institute for Space Studies. Ungar has a Ph.D. in Physics from the City University of New York. His current work emphasizes the use of remote sensing techniques for agricultural applications. He has constructed computer algorithms for the digital processing of LANDSAT and other remotely sensed data with emphasis on simulation of advanced sensor systems. In the past, he has contributed to NASA's Global Atmospheric Research Program (GARP) and is responsible for the technique employed in the GARP weather model for determining cloud height from satellite data. Ungar has conducted astrophysical research at NASA and Columbia University and has delivered several papers on nuclear energized stellar pulsations. He has also performed research in Nuclear Magnetic Resonance and Infrared and Atomic Absorption Spectroscopy at Columbia University.

ABSTRACT

A computerized geographic information system for management of ground truth has been designed and implemented to relate MSS classification results to in situ observations. The ground truth system transforms, generalizes and rectifies ground observations to conform to the pixel size and shape of high resolution MSS aircraft data. These observations can then be aggregated for comparison to lower resolution sensor data. Construction of a digital ground truth array allows direct pixel by pixel comparison between classification results of MSS data and ground truth. By making comparisons, analysts can identify spatial distribution of error within the MSS data as well as usual figures of merit for the classifications. Use of the ground truth system permits investigators to compare a variety of environmental or anthropogenic data, such as soil color or tillage patterns,

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with classification results and allows direct inclusion of such data into classification operations. To illustrate the system, examples from classification of simulated Thematic Mapper data for agricultural test sites in North Dakota and Kansas are provided.

INTRODUCTION

Application of remote sensed data is dependent to a large degree on the ability of the data to be classified into a series of human-perceived land cover classes which have meaning within some social context (i.e., scientific, economic, medical). The process of relating and verifying sensor data relative to ground cover has been a major portion of remote sensing research and has become known as ground truthing.[1] One of the problems that is both conceptually and practically difficult is relating ground observations about predefined spatial units (such as crop type and state in a specific agricultural field) to areally extensive, spatially continuous data provided by airborne and spaceborne remote sensors. The purpose of this paper is to describe how, in the case of MSS data, the conversion process is accomplished and the ways that the converted ground truth is manipulated in a spatial array to aid in analysis of sensor data. This ground truth management system was designed for a series of investigations conducted at NASA, Goddard Institute for Space Studies (GISS) to determine appropriate parameters for the proposed Thematic Mapper (TM) MSS planned for LANDSAT-D.

SYSTEM DEVELOPMENT

To assess the capabilities of the proposed Thematic Mapper instrument, 24-channel MSS aircraft data with 6 meter field-of-view were spatially degraded to create simulated Thematic Mapper outputs.[2] In order to measure the accuracy with which the simulated MSS data could be classified for the crop classes known to exist in the test sites studied, it was necessary to develop computer files that could relate the ground identified thematic classes with the computer classification results. Sources of information used to construct ground truth files to support the analysis of simulated data were as follows:

<u>Finney County, Kansas</u>
- LACIE Intensive Study Site, 1/24,000 Land Use Map, June, 1974, (with thematic overlays).
- LACIE Ground Truth Inventory Form, July, 1975.
- LACIE Ground Truth Periodic Observation Form, June 6, 1975 and July 6, 1975 (with maps).
- 1/20,000, RC-10, 9" color and CIR aerial photography flown June 6 and August 15, 1975 (simultaneously acquired with 24-channel MSS data).

Williams County, North Dakota
- LACIE Intensive Study Site, 1/24,000 Land Use Map, June, 1974 (with thematic overlays).
- LACIE Ground Truth Inventory Form, June, 1975.
- LACIE Ground Truth Periodic Observation Form, June 23 and August 15, 1975 (with maps).
- 1/20,000, RC-14, 9" color and CIR aerial photography flown June 22 and August 15, 1975 (simultaneously acquired with 24-channel MSS data).

These data sources were combined into digital ground truth files for each flight line of MSS data in the series of steps illustrated in Figure 1.

LACIE inventory and observation data were used to identify a set of informational classes appropriate for the test sites for each acquisition time. The informational classes used in the analysis of simulated MSS data were as follows:

Finney County, Kansas, June 9 and July 6, 1975
1. Wheat
2. Corn
3. Alfalfa
4. Grain Sorghum
5. Summer Fallow
6. Recently Tilled
7. Other

Williams County, North Dakota, June 22, 1975
1. Emergent Wheat
2. Recently Tilled/Summer Fallow
3. Pasture
4. Other

Williams County, North Dakota, August 15, 1975
1. Wheat
2. Summer Fallow
3. Pasture
4. Other

In the Finney County case, the informational classes used were the same for both dates studied. In Williams County, this could not be done. The June 22 mission was flown shortly after planting, and the spring wheat present was sensed in two distinct states (recently tilled/drilled and post emergent), which had to be taken into account in structuring the informational classes listed above.

After the informational classes were determined, each field within the portion of the test site to be analyzed was assigned to a class. It was found that these assignments could not be made based on LACIE products alone because of uncertainties in field boundary locations and in identification of the agricultural uses within the fields. To provide the accuracy necessary to assess the reliability of the TM classification results, it was thought necessary to corroborate the LACIE data with image analysis of simultaneously acquired aerial photography. Fields where boundary and field conditions did not concur with LACIE ground truth and could not be determined from photography alone were

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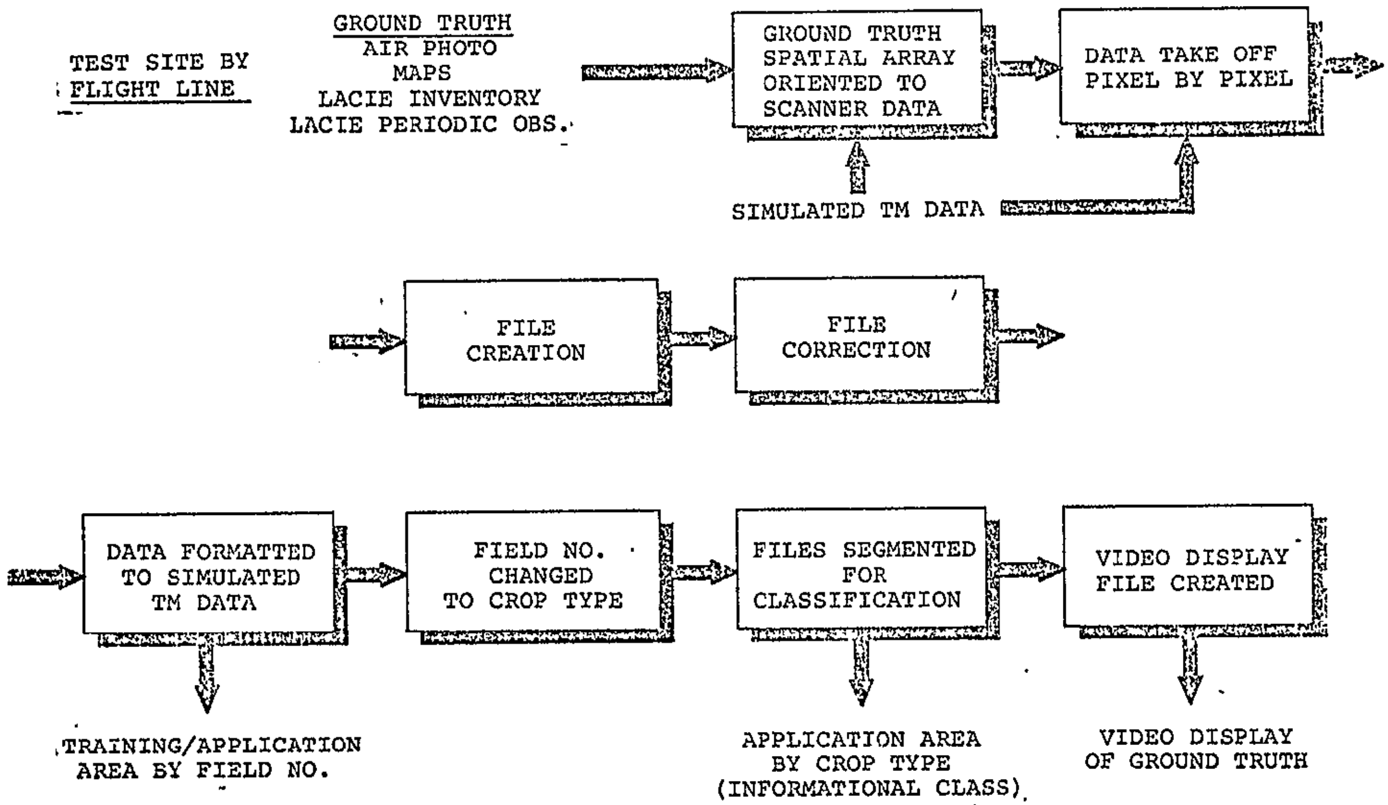

Figure 1. Steps used to create ground truth files for Thematic Mapper studies.

disregarded as ground truth areas. In most cases, culling resulted in 5 to 10% loss of area by flight line in North Dakota, and less than 5% in Kansas.

After all fields were verified, they were proportionately plotted from the aerial photographic base onto a grid defined by the MSS data for the same flight line. The data were then regridded into the simulated TM pixel space with the aid of high resolution MSS gray scale to correct for aircraft pitch, yaw and crab. After each field boundary was plotted, each field or non-agricultural area to be considered in the ground truth was assigned a number. Number assignment was blocked according to crop type, i.e., 1-25 wheat, 26-50 summer fallow, etc.

Data take off was carried out from the pixel gridded ground truth, with each row of data encoded according to the field numbers of pixels it contained. For purposes of standardization, each ground truth array consisted of 256 lines of 30 meter data. Width of the array varied because of flight line position relative to the LACIE test site. Normally, the data consisted of 164 columns of 30 meter pixels, with between 10 and 20% of the sensed area lying outside the truthed area, therefore padded with 0 (zeroes) to make the ground truth array and the simulated TM data array the same dimensions. This provided ground truth arrays of 41,984 for the 30 meter data, corresponding to an area about 5 x 7.5 kilometers.

After data take off was accomplished, each array was subjected to correction by comparison with the original overlay of field numbers and boundaries in pixel space. This correction process was iterative, requiring 3 to 6 reruns until error was removed from the files.

When the files were created, corrected, rectified and verified, they were reformatted to conform to specific classification and display tasks. First, the ground truth areas where data were ambiguous were masked out of the ground truth array. These areas were removed from consideration in the development of figures of merit for the supervised classification series that followed. Also, separate files were created for training areas at this point. Each training area represented approximately 5% of the total ground truthed area. The mask file was further used to provide statistics on per field performance of the data for input into studies of field size versus classification accuracy. This was possible because each field number in the array was associated with a specific LACIE field number, allowing the extraction of acreage from the LACIE notes as well as directly from the pixel counts.

The next step was to change the field numbers into crop types that corresponded to the pre-established informational classes, after which the single file was segmented into four sections for the 30 meter data. Segmentation was necessary for compatibility with GISS software used in classifying the large application areas. Ground truth was reformatted a final time to allow for display of a thematic map showing crop classes on a color video system.

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SYSTEM USE

Figures of Merit

Conventional assessment of the accuracy of crop type classification relies on measurement of areas assigned to a given crop by field survey or air photo mensuration. After the crop area is established by these external survey methods, figures of merit are determined by comparing ground surveyed acreages for each crop versus the acreages determined by the classification. Figures of merit are influenced by a number of spatial criteria and generalizations that are independent of the classification and are inherent in the ground survey used as a comparison. This problem is reduced by using the ground truth management system at GISS, because the ground truth has been treated in such a manner that it is directly comparable, pixel by pixel, with the MSS data being classified. Essentially, the ground truth has been transformed into MSS scanner data format so that all figure-of-merit comparisons are made as an additional job step in the computer classification sequence.

The use of this type of ground truth file or data channel is important in studying figure-of-merit-related classification problems. These include: 1) the role of field size and shape, 2) the impact of boundary pixels, and 3) the consequences of within-field homogeneity.

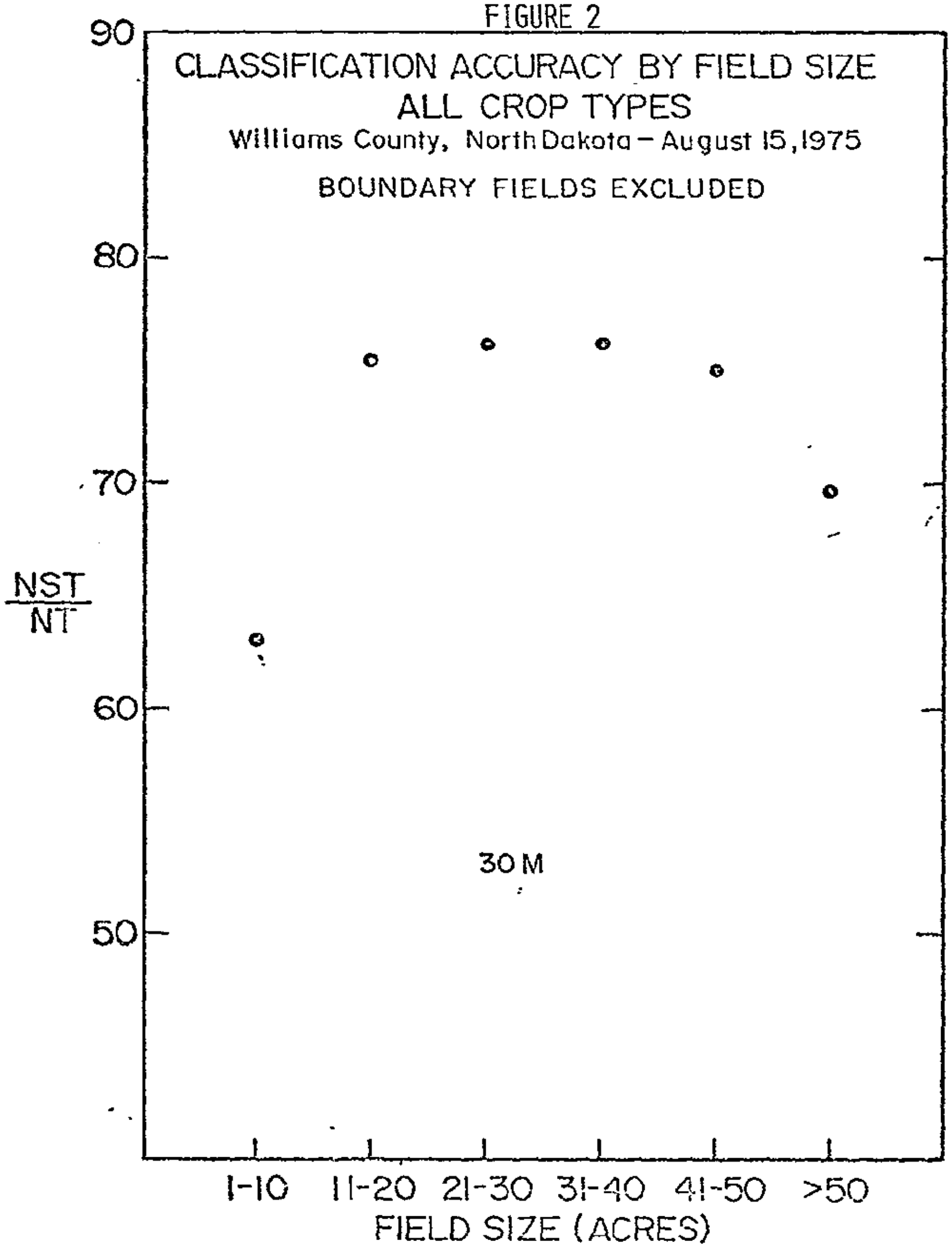
In the past, most figures of merit have been expressed in terms of area extensive training or classification sites representing an ensemble of crop and other land cover types. Such aggregate figures were difficult to reduce to disaggregate levels where individual fields could be identified as discrete land cover units and determinations of classification results on a field by field basis, independent of crop type, could be undertaken. Figure 2 plots classification accuracy as a function of field size for a 30 meter simulated MSS resolution. The ability to produce such an analysis rests on the ground truth management system, which allows the computer to organize classification results along smaller spatial units (in this case, fields) which have been preidentified in the ground truth array.

Environmental Partitioning

It has become widely recognized that classification problems associated with the extension of training results over larger areas arise, in part, because of changes in the relative importance of various environmental and social factors determining land cover at any single place. However, the impact on classification of an individual environmental factor and the factor's spatial variation is not well understood. The ground truth system developed at GISS has permitted investigation of selected environmental and social factors that might influence classification of land cover.

For agricultural studies, factors possibly influencing classification are assigned to two categories--human management and physical environment. Variables found in land

FIGURE 2


CLASSIFICATION ACCURACY BY FIELD SIZE
ALL CROP TYPES
Williams County, North Dakota – August 15, 1975
BOUNDARY FIELDS EXCLUDED
90
80
70
60
50
NST/NT
30 M
1-10
11-20
21-30
31-40
41-50
>50
FIELD SIZE (ACRES)

management (farming practices) are input by use of the field number ground truth array. Fields with a similar set of management practices are grouped into a class in the figure-of-merit job step that follows classification. Essentially, this allows classification to be conducted on parameters such as planting data, tillage direction, field orientation as well as the more common classification criteria of crop type. For physical environment factors, a separate ground truth file must be established, following the complete file creation process outlined in Figure 1, because the spatial distribution of physical environment factors is independent of fields.

SUMMARY

This paper has described a different approach to ground truth management. It varies from practices normally used in computer processing of remotely sensed data through spatially referencing the ground truth to sensor output. This referencing allows disaggregation of figures of merit to the level of a ground truth collection unit (usually a field in agricultural studies) and direct pixel by pixel comparison between ground truth and sensor data.

Usage of this system to understand how classifications extract information themes from the landscape has just begun. As a start, its utility has been demonstrated in the simulated Thematic Mapper studies of resolution, band configuration, and the influence of field size on classification accuracy.

REFERENCES

1. Lougeay, Ray (1976), "Selected Bibliography of References Related to Ground Truth," Remote Sensing of the Electro-Magnetic Spectrum, Vol. 3, No. 4 (Oct.), pp. 17-20.

2. Landgrebe, D. A., (1976), Final Report NASA Contract NAS9-14016, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana.

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