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IT-J2-04369 TM-85242
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Inventory Technology Development

A Joint Program for
Agriculture and
Resources Inventory
Surveys Through
Aerospace
Remote Sensing

SEPTEMBER 15, 1982

THEMATIC MAPPER PERFORMANCE ASSESSMENT IN RENEWABLE RESOURCES/AGRICULTURAL REMOTE SENSING - INITIAL SCENE QUICK-LOOK ANALYSIS

LANDSAT 4 IMAGE DATA QUALITY ANALYSIS (LIDQA) PROGRAM INVESTIGATION

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(E83-10191) THEMATIC MAPPER DATA QUALITY AND PERFORMANCE ASSESSMENT IN RENEWABLE RESOURCE/AGRICULTURAL REMOTE SENSING (NASA) 126 p HC A07/MF A01 CSCL 02C
N83-20313
Unclas
G3/43 00191

UNITED STATES DEPARTMENT OF AGRICULTURE
DEPARTMENT OF COMMERCE UNITED STATES OF AMERICA
U.S. DEPARTMENT OF THE INTERIOR MARCH 3, 1849
UNITED STATES OF AMERICA

Earth Resources Applications Division
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Houston, Texas 77058

1. Report No.
JSC-18579; IT-J2-04369

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle

THEMATIC MAPPER DATA QUALITY AND PERFORMANCE ASSESSMENT
IN RENEWABLE RESOURCE/AGRICULTURAL REMOTE SENSING

5. Report Date
November 1982

6. Performing Organization Code

7. Author(s)

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8. Performing Organization Report No.
SG, SH, SA

9. Performing Organization Name and Address

Earth Resources Research Division and Earth Resources
Applications Division, Space and Life Sciences Directorate,
NASA/JSC, Houston, TX

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

13. Type of Report and Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes
This report was prepared at JSC for the Landsat-4 Image Data Quality Analysis (LIDQA) program conducted by Goddard Space Flight Center. The "Quick-Look" team members of Lockheed/EMSCO contributed significantly to the report.

16. Abstract

A "quick look" investigation of the initial Landsat-4, Thematic Mapper (TM) scene received from Goddard Space Flight Center (GSFC) was performed to gain early insight into the characteristics of TM data. The initial scene, containing only the first four bands of the seven bands recorded by the TM, was acquired over the Detroit, Michigan, area on July 20, 1982. It yielded abundant information for scientific investigation. A wide variety of studies were conducted to assess all aspects of TM data. They ranged from manual analyses of image products to detect obvious optical, electronic, or mechanical defects to detailed machine analyses of the digital data content for evaluation of spectral separability of vegetative/nonvegetative classes. These studies were applied to several segments extracted from the full scene. No attempt was made to perform end-to-end statistical evaluations. However, the output of these studies to identify a degree of positive performance from the TM and its potential for advancing state-of-the-art crop inventory and condition assessment technology.

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17. Key Words (Suggested by Author(s))

Crop Condition
Crop Inventory
Data Quality
Image Products
Landsat-4
Remote Sensing
Renewable Resources
Signal-to-noise
Spatial Resolution
Spectral Separability
Thematic Mapper
Vegetative Classes

18. Distribution Statement

This document was prepared in open format to accomodate viewgraph reproductions and study data.

19. Security Classif. (of this report)

20. Security Classif. (of this page)

21. No. of Pages

22. Price*

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JSC Form 1424 (Rev Nov 75)

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THEMATIC MAPPER PERFORMANCE ASSESSMENT IN RENEWABLE RESOURCES/AGRICULTURAL REMOTE SENSING

INITIAL SCENE QUICK-LOOK ANALYSIS

PREPARED TO SUPPORT
THE
LANDSAT-4 IMAGE DATA QUALITY
ANALYSIS (LIDQA) PROGRAM INVESTIGATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

SEPTEMBER 1982

PREFACE

This report was prepared in support of the Landsat-4 Image Data Quality Analysis (LIDQA) Program. It represents an early activity of the "Thematic Mapper Data Quality and Performance Assessment in Renewable Resources/Agricultural Remote Sensing" investigation in LIDQA, and is being conducted at the Johnson Space Center (JSC) under Dr. Jon D. Erickson and Robert B. MacDonald, co-principal investigators.

This portion of the investigation and the compilation of this report was led by Robert M. Bizzell, Harold L. Prior and Milton C. Trichel of the Earth Resources Applications Division. The major contributors to this report were the members of the "Quick Look" Team from the Lockheed Engineering and Management Services Company (LEMSCO).

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Special acknowledgements go to William Dowdy, U.S. Department of Agriculture (USDA) for his contribution in the coordination and collection of agricultural ground data. Special acknowledgements also go to the personnel from the Earth Resources Research Division who developed the data systems capabilities and provided consultation necessary to perform key data processing and analyses required for this study: Jimmy R. Gilbert, Charles B. Wheelock and W. Dan Womack.

JSC TM QUICK LOOK REPORT

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INTRODUCTION

INTRODUCTION

The eagerly awaited Thematic Mapper (TM) was successfully launched with the Landsat-4 in July of 1982. The increased spatial resolution (30 meters), additional spectral bands (3 visible, 3 infrared, and on thermal) of narrower band width and more optimum spectral placement, improved signal to noise ratio, and improved ground data processing - all relative to the reliable Landsat Multispectral Scanner (MSS) - offers much promise for additional information for crop inventory and condition assessment technology. A quick look analysis in support of the Goddard Space Flight Center (GSFC) Landsat-4 Image Data Quality Analysis (LIDQA) Program was planned and implemented to gain early insight into the characteristics of the TM. The initial TM scene received from GSFC contained only the first 4 bands of the total 7-band TM sensor. This scene was acquired over the Detroit, Michigan, area on July 20, 1982. It yielded an abundance of information for scientific investigation. A wide variety of studies were conducted to assess all aspects of the TM data; from manual analyses of image products to detect obvious optical, electrical and/or mechanical defects to detailed machine analyses of the digital data content for evaluation of spectral separability of vegetative/nonvegetative classes. These studies were applied to several data segments extracted from the full scene. The findings from these studies continue to compile an exhaustive list and no attempt was made here to perform end-to-end statistical evaluations. However, the output of these studies do identify a degree of positive performance from the TM and its potential for advancing the state-of-the-art in crop inventory and condition assessment technology.

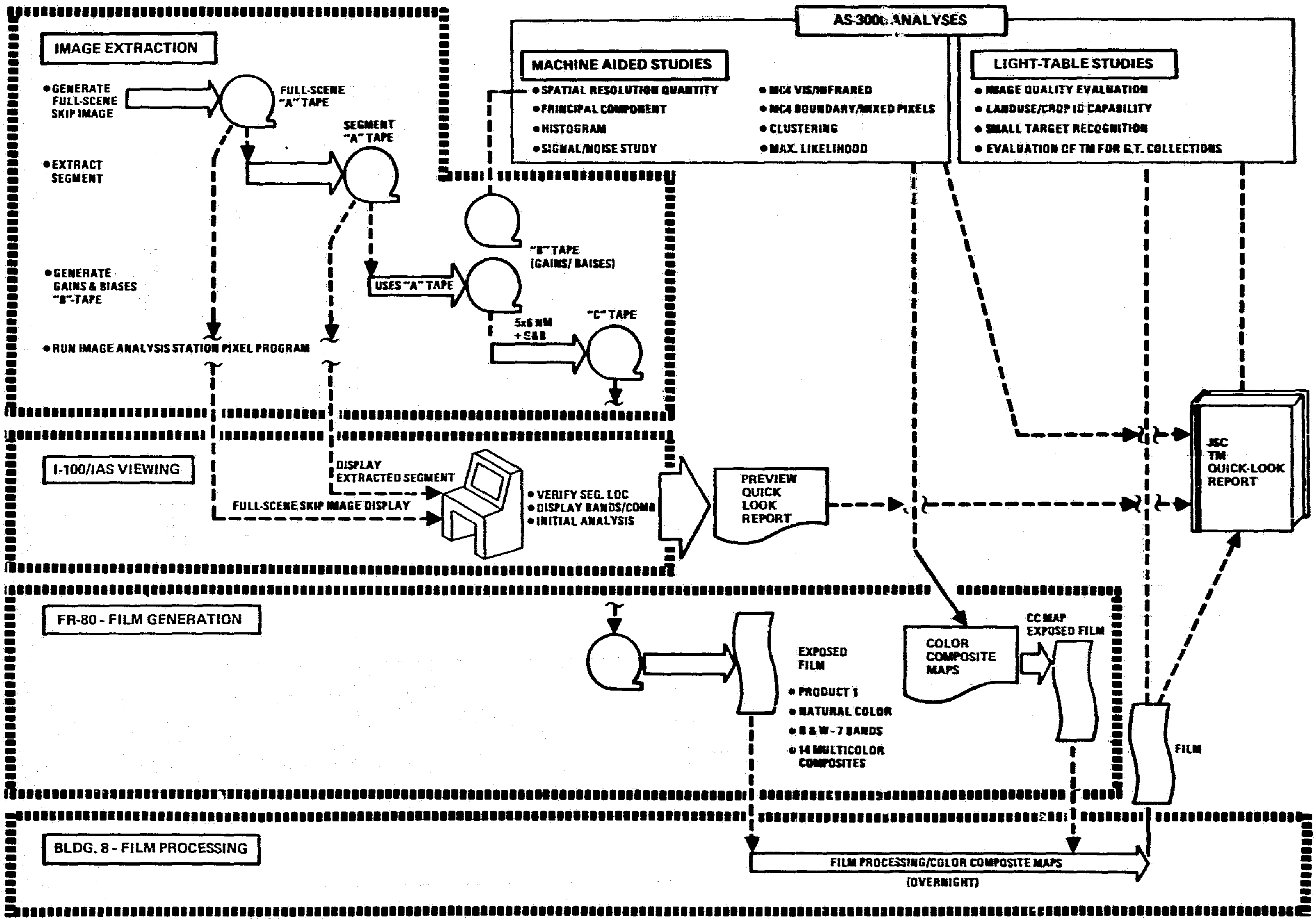
INTRODUCTION

JSC TM QUICK LOOK SITE SELECTION

GENERAL CRITERIA FOR SEGMENT SELECTION:

- Constrained to 4-band frame acquired over Detroit, Michigan, July 20, 1982.
- Constrained by limited ground data collection capability.
- To capture a variety of conditions and land-use groups.
- Contribution to a number of studies.
- The location on the full frame.

JSC THEMATIC MAPPER QUICK LOOK STUDIES SCHEDULE



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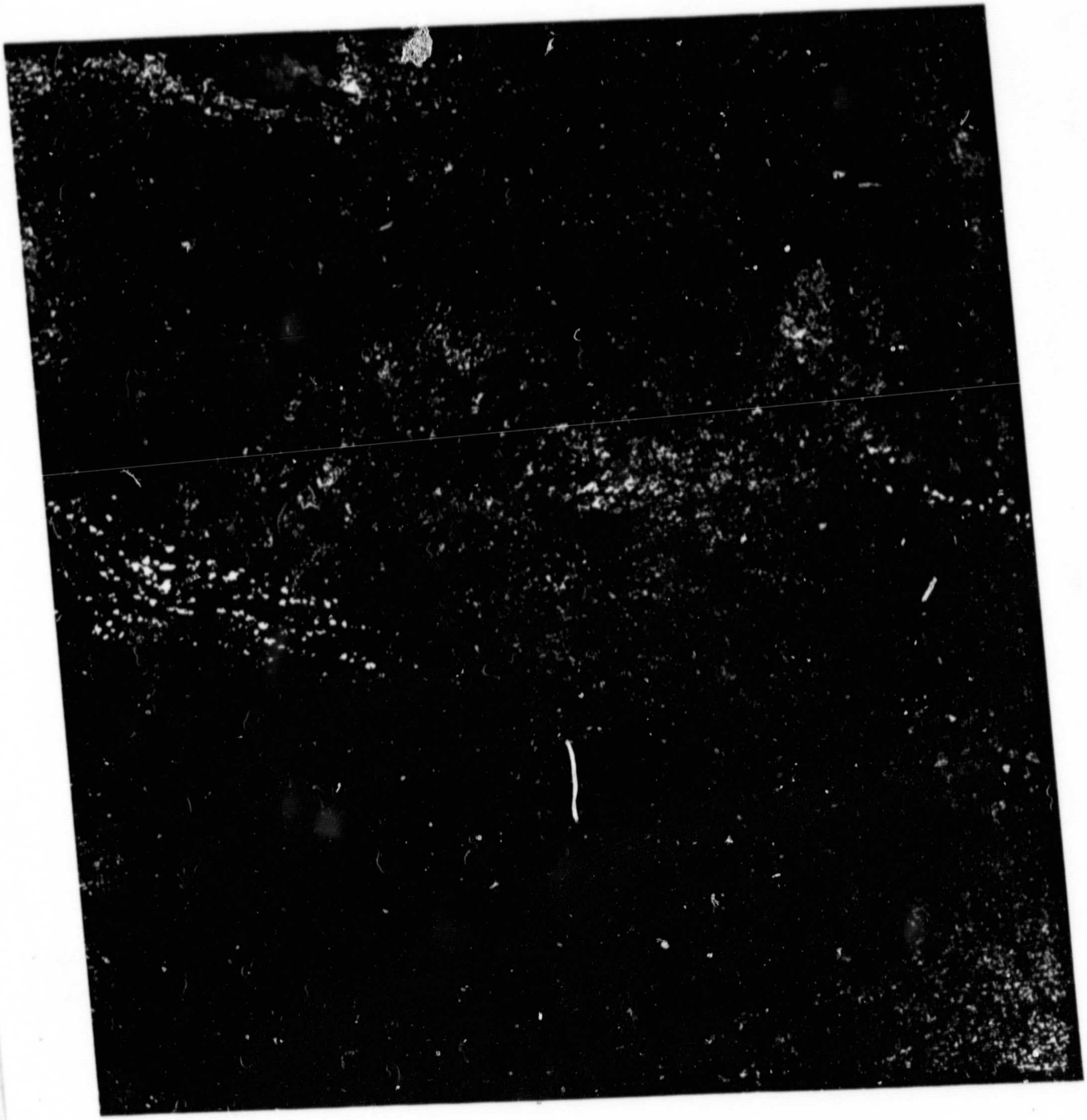

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SEGMENT RATIONALE FOR INITIAL TM ANALYSES

1. Candidate for ground data collection evaluation - Tecumseh, Michigan (9645).
   - Contains -
     - Agriculture
     - Towns
     - Natural Vegetation
     - Small airport
     - Water
   - Located totally in one county.
2. East Toledo (9646)
   - Contains -
     - Urban/industrial
     - River
     - Large vegetated area
     - Resolution targets
   - Analyst familiar with this area
3. Sandusky (9647)
   - Contains -
     - Bridges for resolution targets
     - Some mining/quarries
     - Large water bodies for signal/noise study
4. Ann Arbor (9648)
   - Contains -
     - The city and university
     - Mining
     - Agriculture

5. West of Toledo (9649)
    - Contains -
        - Quarry/mining
        - Urban/agricultural transition
        - Natural vegetation
6. Detroit Airport (9650)
    - Contains -
        - Resolution targets
        - Urban
        - Agriculture
7. Canadian Site (9651)
    - Contains -
        - Agriculture - different mix from site #9645
        - Water target
8. 100% Water Site (9652)
    - Test
9. Fulton County, Ohio Blind Site (0231)
    - Contains -
        - Agriculture
        - Small town
    - Previously a ground truth site

TM DETROIT SCENE QUICK LOOK

Quick Look Priority	Segment	Name	Purpose
1	TM 9645 IMAGE	Tecumseh	Agriculture
2	TM 9646 IMAGE	East Toledo	Resolution
3	TM 9647 IMAGE	Sandusky	Signal/Noise
4	TM 9648 IMAGE	Ann Arbor	Resolution
5	TM 9649 IMAGE	West Toledo	Agriculture
6	TM 9650 IMAGE	Detroit Airport	Public Information
7	TM 9651 IMAGE	Canada	Foreign Agriculture
8	TM 9652 IMAGE	Water (100%)	Test
9	TM 0231 IMAGE	Fulton Blind Site	Ground Truth (Agriculture)

1.0 PRELIMINARY
TM DATA QUALITY ASSESSMENT
STUDIES

1.1 IMAGE QUALITY STUDY

- Rationale:

Equipment malfunctions, inadequate aspect corrections, clouds and processing errors can degrade or negate the informational value of imagery.

- Objective:

A qualitative evaluation was made by an image analyst on the Quick Look imagery products to detect and report any degradation which may have occurred during extraction and processing, and to report any excessive geometric distortions or clouds/haze.

- Scope:

The evaluation was subjective in nature and based on a single multi-band thematic mapper scene. It is not intended that this evaluation will overlap with other qualitative studies to be made at the same time.

- Approach:

1. The imagery products were visually examined to determine the extent of degradation present from each of the following potential causes: mechanical, electro-optical, processing, or atmospheric. Greater than 10% random or sporadic degradation was considered to be unacceptable; greater than about 40% degradation from localized factors such as clouds was considered unacceptable.
2. Shape and alignment of features identifiable in the imagery was compared with corresponding features on available maps to detect any distortions in shape and direction.
3. A qualitative comparison was made of pixels generated in the point versus character mode of image product generation.

- Output:

1. Description of mechanical, electro-optical, atmospheric, and film processing effects noted on TM image products.

- Results:

  The real imagery seems to have nearly the same characteristics as the simulated imagery with respect to pixel purity (and resolution), within-field variation, scan line clarity, etc., with exception of the "true color" differences noted in the paragraph on Atmospheric Effects. In short, it appears the simulators did a good job simulating Thematic Mapper imagery.

  The quality of the geometric corrections also appears to be excellent in the 9 segments generated of land areas. Straight lines appear as straight lines, as evidenced by section lines in Segment 0231 (an agricultural segment) and as evidenced by runways at Detroit Airport in Segment 9650. No circular features were found, but an oval racetrack in Segment 9649 appeared oval in shape as it should have appeared.

  - MECHANICAL EFFECTS

    There was no evidence of degradation due to vibration or other mechanical causes in any of the segments extracted.

  - ELECTRO-OPTICAL EFFECTS

    The all-water segment (TM 9652) had unusual coloration. The water did not look blue using the false color infrared and "true color" generation techniques for land areas. There were almost no blue pixels, and brown or red pixels predominated. Detectors and their associated "sweep" was evident in both the color and B/W products. Occasional "line file" was also noted.

  - ATMOSPHERIC EFFECTS

    The overall loss of green and blue in channels 1 and 2 was greater than anticipated in the "true color" simulations using channels 1, 2, and 3. All of the vegetation in the TM true color scenes is brown, with only a few olive pixels being detectable under magnification. While part of the loss of green may have been caused by the image generation and processing techniques, it is not unusual for blue and green reflected wavelengths to be affected by atmospheric haze. Further experimentation will be needed to gain a better understanding of the causes of degradation in the "true color" imagery composites.

- FILM PROCESSING

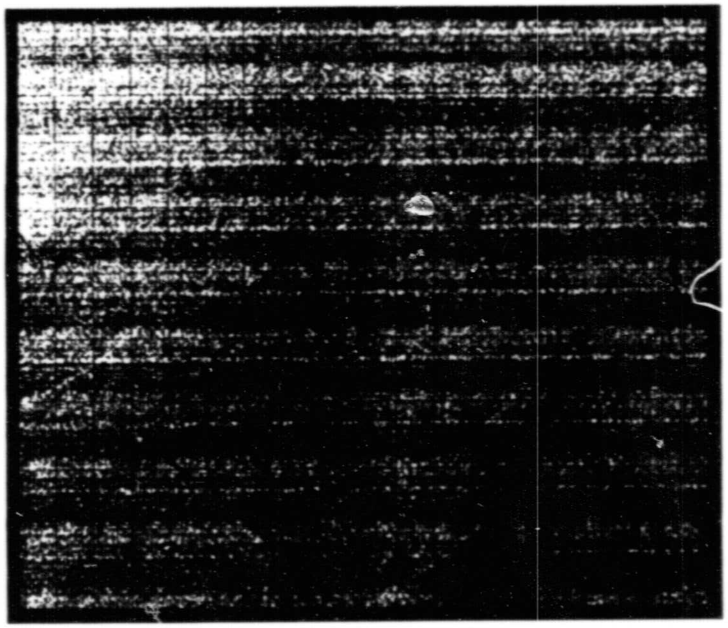
There are both operator-related and software-related comments to be made.

Operator-related

With respect to FR-80 operation and film processing: The FR-80 settings appear to have caused differences in overall brightness of the imates generated on September 10 and 11; i.e., those generated on September 11 were generally brighter. On a case-by-case basis, however, there were detectable differences in brightness within each "batch" generated. Some variation could have resulted during the lab processing.

Software-related

Some adjustment in the software that "scales" the data may be in order. The full range of reflected values is not captured consistently in the image products and in some cases is spread too far as in the "water" segment. Examination of several channel 4 black and white images revealed that green vegetation is being partially dropped out in some cases, with only C.I.R. "bright" red showing up in the black and white images. For example, when viewing channel 4 for Segments 0231 and 9645 (both generated on September 11) virtually all of the vegetation in Segment 9645 appears as shades of gray, but in Segment 0231, many of the vegetated fields look no different than plowed fields.



ALL WATER, #9652, COLOR (CH 1, 2, 3)

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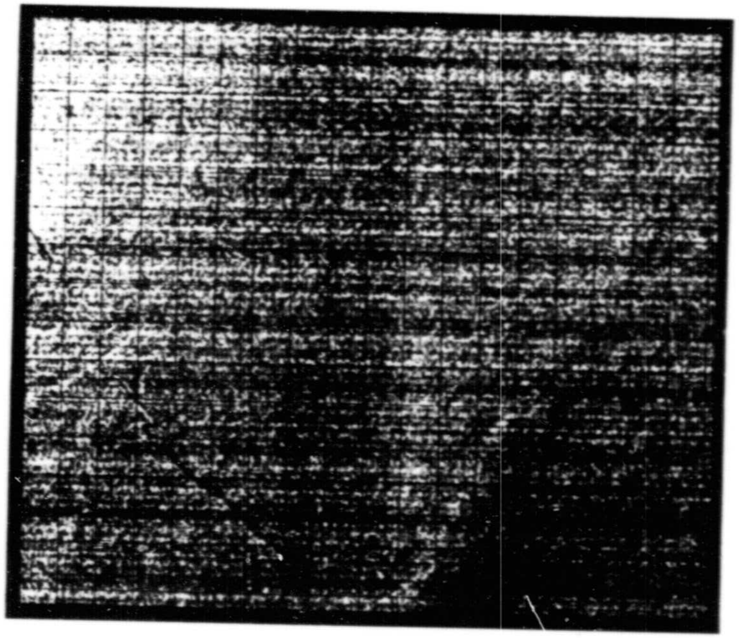

ALL WATER, #9652, COLOR IR (CH 2, 3, 4)

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1.2 SPATIAL RESOLUTION QUANTIFICATION STUDY: AN ANALYSIS OF INTERFACE ZONES

- Objective:

  Examine surface type interfaces as an aid in understanding boundary region spatial and spectral characteristics.

- Approach:

  Analysis of boundary regions between agricultural fields of the same and different crop types.

- Rationale:

  1. Aid in labeling target definition (spatial and spectral).
  2. Aid in labeling and allocation of boundary zones in proportion and area estimation.
  3. Aid in the development of classification systems with different levels of generation.

- Products:

  - Band-to-band plots of several boundary traces.
  - Estimate of the Modulation Transfer Function for each channel.

- Results:

  By examination, the scanner response delay performance for each channel matches or exceeds published specifications. Overshoot specifications may not be met, although the influence of within field reflectance variability on perceived overshoot is unkown.

  MTF's generated for each channel show a system performance below what is expected. This is probably not a true indicator of system performance since derivation of the MTF was directly tied to the mathematical function fit to the TM edge traces. The selected function did not satisfactorily capture the abrupt shift in reflectance values measured by the sensor in each channel at the boundary.

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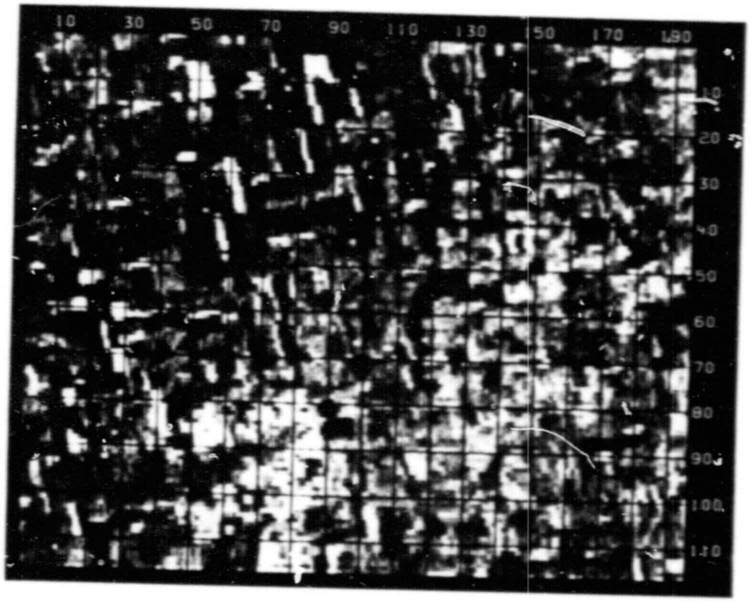
Creation of the TM Channel 1 Smooth Edge Trace Overlay:

An ideal square pulse approximation of the boundary, indicated by the solid line, was convoluted with a 30m IFOV, a response delay time of 11.6 μsec settling time. The convoluted pulse is shown with a dashed line. The results discuss how the empirical data is related to the convoluted pulse that incorporates preflight system specifications.

SEGMENT 231 — JULY 10, 1979, MSS.



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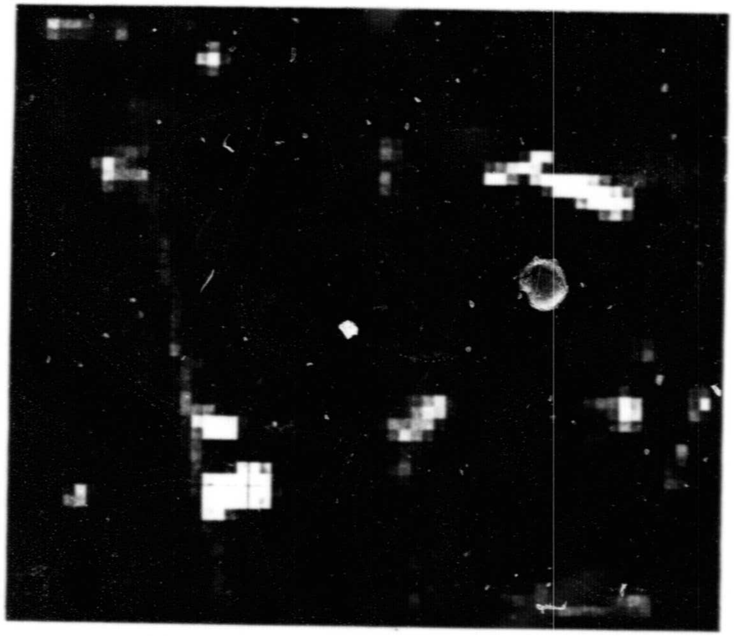
SEGMENT 231 FULTON, OHIO

EXTRACTED SUBSEGMENT SHOWN BELOW IS 60 LINES X 60 PIXELS WITH AN UPPER LEFT CORNER COORDINATE OF X = 120
Y = 140



THE TM EDGE TRACE FOLLOWS THE DASHED LINE, FROM LEFT TO RIGHT, ACROSS THE SOLID LINE THAT REPRESENTS THE BOUNDARY BETWEEN THE SOYBEAN FIELD (LEFT) AND THE CORN FIELD (RIGHT).

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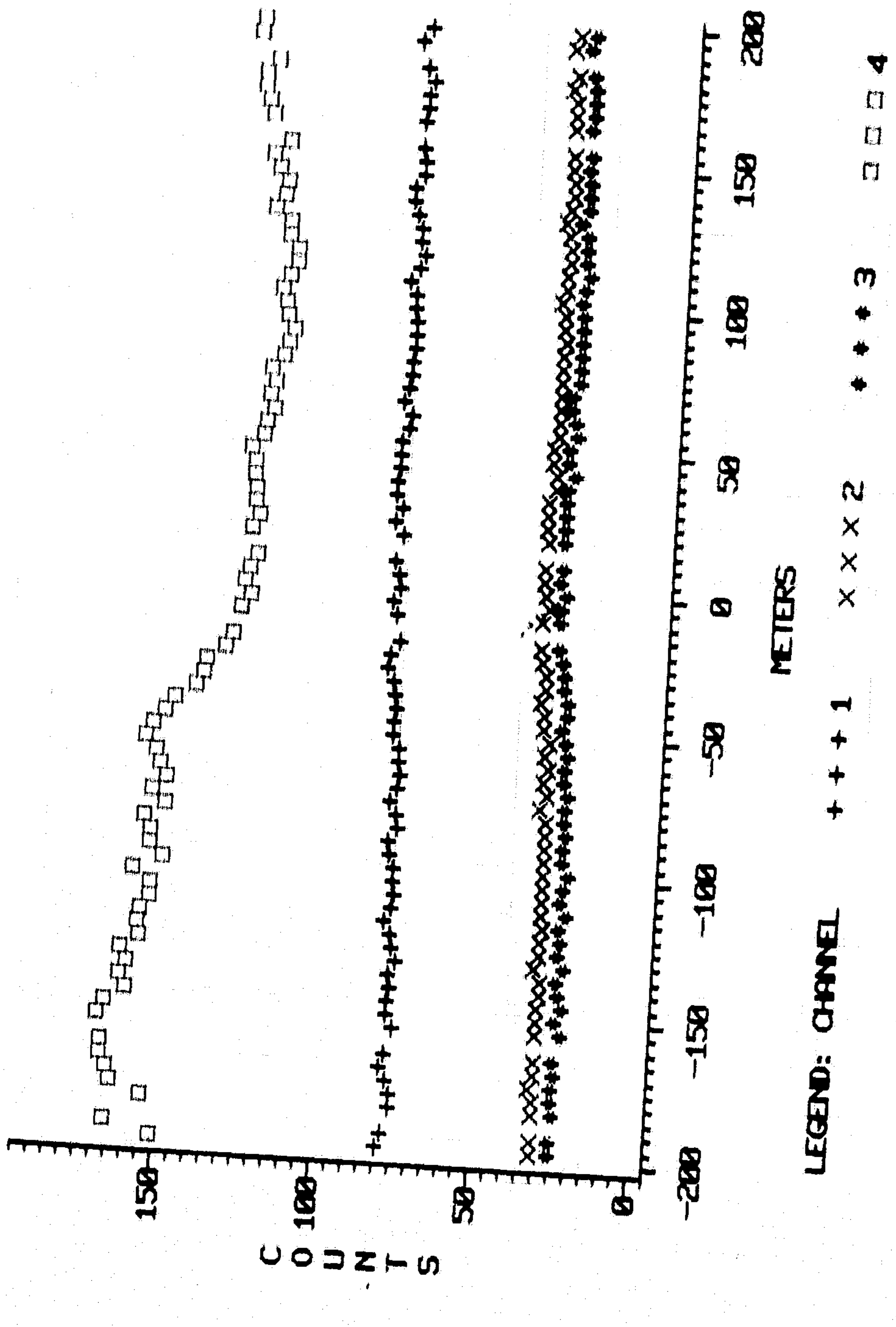
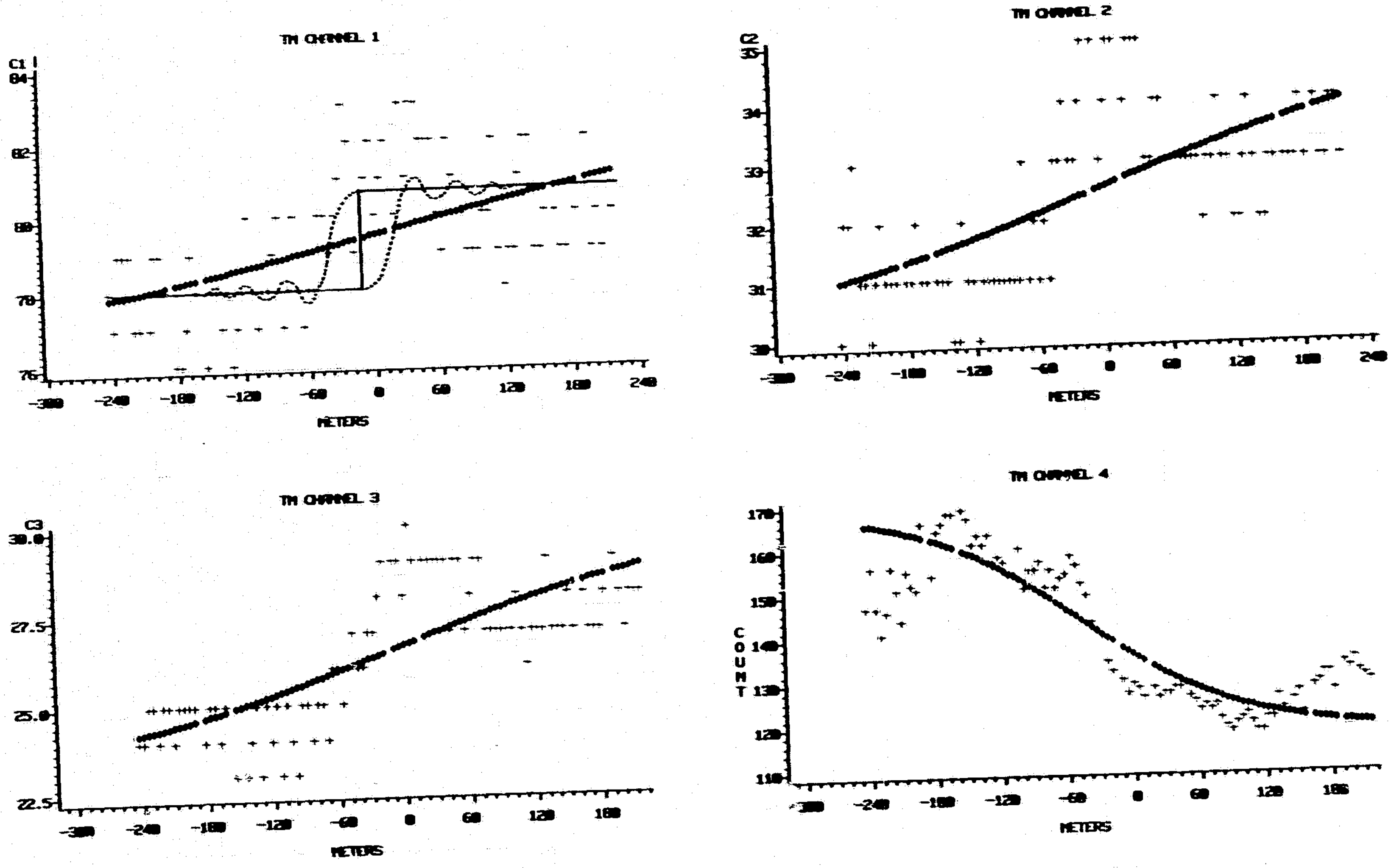
LANDSAT TM EDGE TRACES



SMOOTH EDGE TRACE



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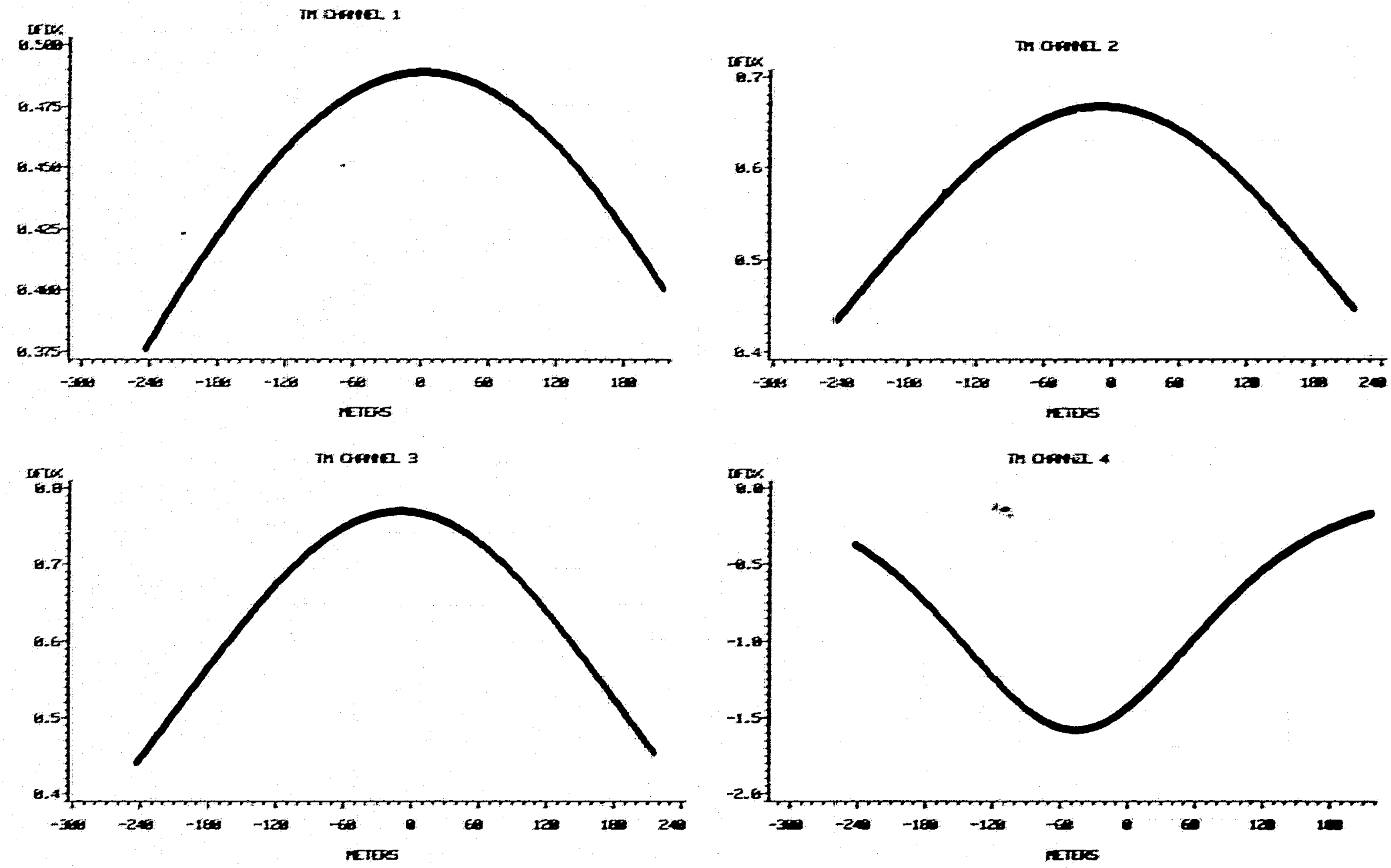
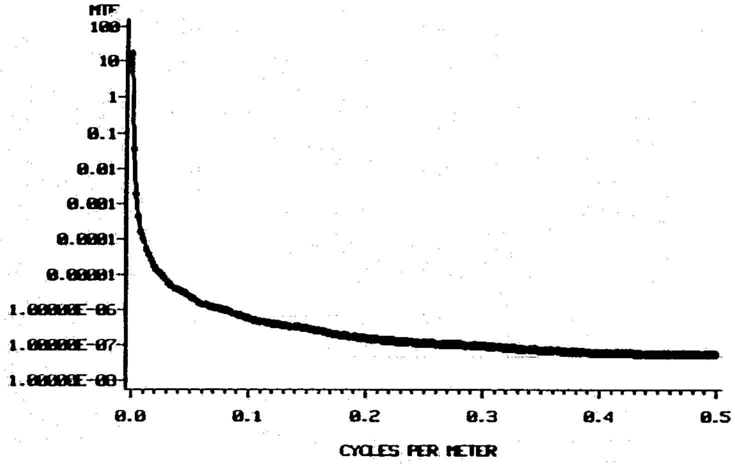
DERIVATIVE OF LINESPREAD FUNCTION

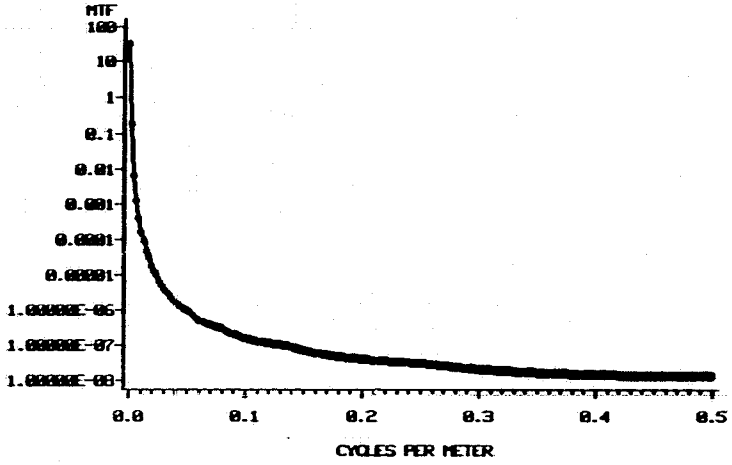


MODULATION TRANSFER FUNCTION

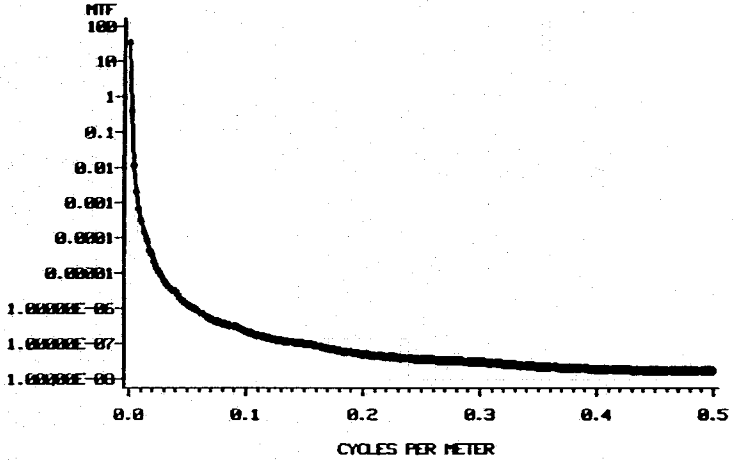
TM CHANNEL 1



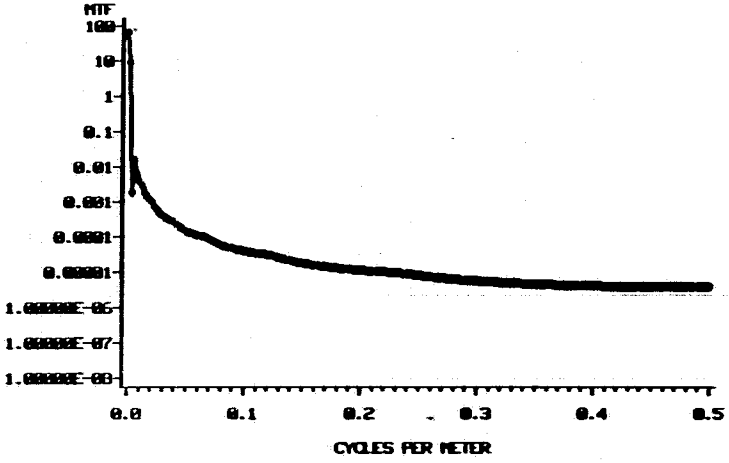
TM CHANNEL 2



TM CHANNEL 3



TM CHANNEL 4



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1.3 SIGNAL/NOISE RATIO STUDY

- Rationale:

  To get an indication of the noise that exists in the sensor on each band by examining the signal/noise (S/N) in the entire system and to provide understanding regarding the potential effect on vegetation studies.

- Objective:

  Determine the S/N in each TM band and compare it to the specified S/N of the Thematic Mapper.

- Scope:

  One acquisition of each of the 4 bands for each TM segment which contains identifiable homogeneous targets.

- Approach:

  - Generate grey maps of each segment by band.
  - Identify homogeneous targets on the TM image for each band.
  - Generate histogram for each target and band to acquire the mean and standard deviations of the target counts.
  - Calculate the radiance and S/N for eaach target and band.
  - Plot the observed S/N and the pre-flight specifications and compare results.
  - S/N for each sample = $\frac{\text{counts mean}}{\text{counts standard deviation}}$
  - Radiance for each sample = A + B (counts mean)
    for Thematic Mapper, $A \approx 0.00$
    for each band $B = \frac{\text{Maximum Scene Radiance}}{255}$ from advertised specifications

- Output:

  Plot of S/N by radiance for each band.

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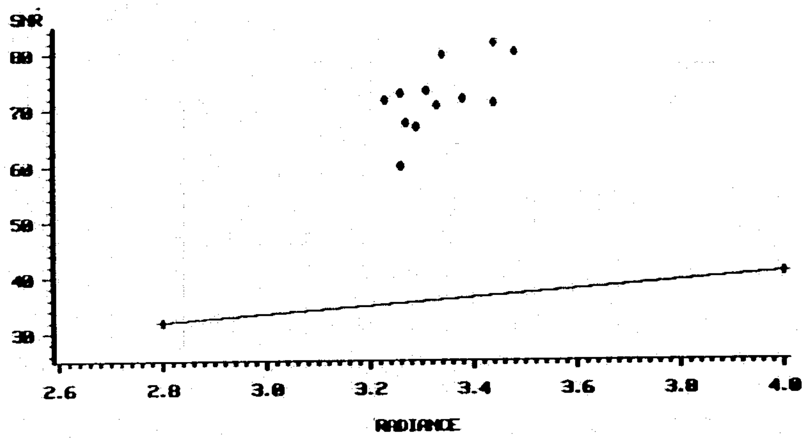
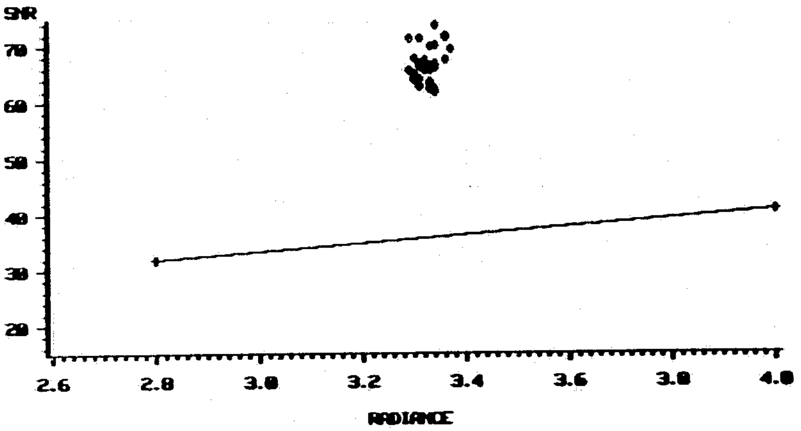
TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND1
SEGMENT 9647



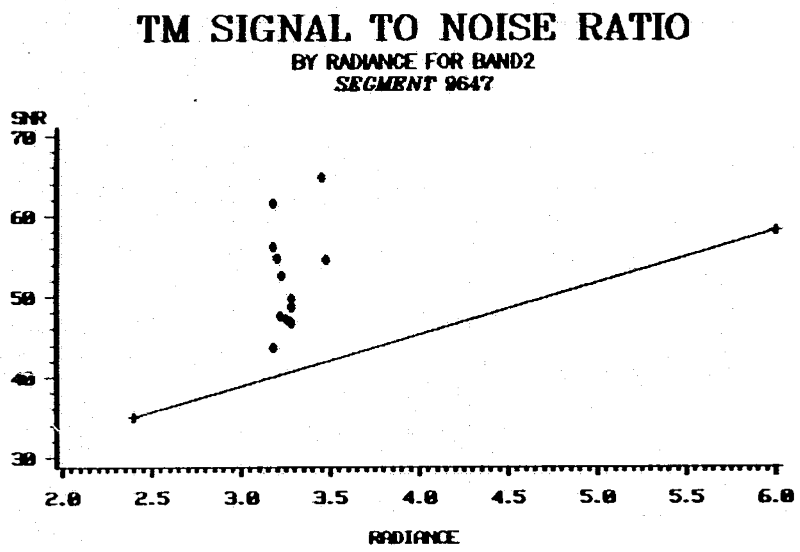
TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND1
SEGMENT 9652

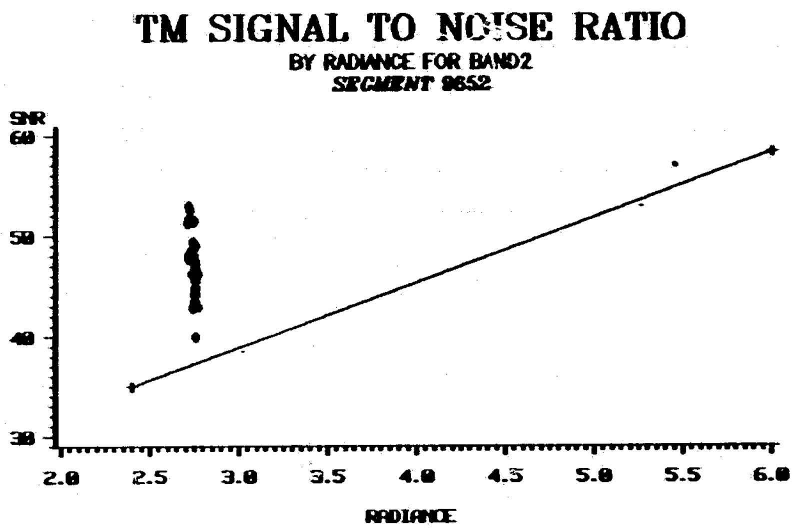


* SELECTED SAMPLES   + ADVERTISED SPECIFICATIONS

Higher values for S/N indicate that specifications are being exceeded



TM SIGNAL TO NOISE RATIO
BY RADIANCE FOR BAND2
SEGMENT 9647



TM SIGNAL TO NOISE RATIO
BY RADIANCE FOR BAND2
SEGMENT 9652

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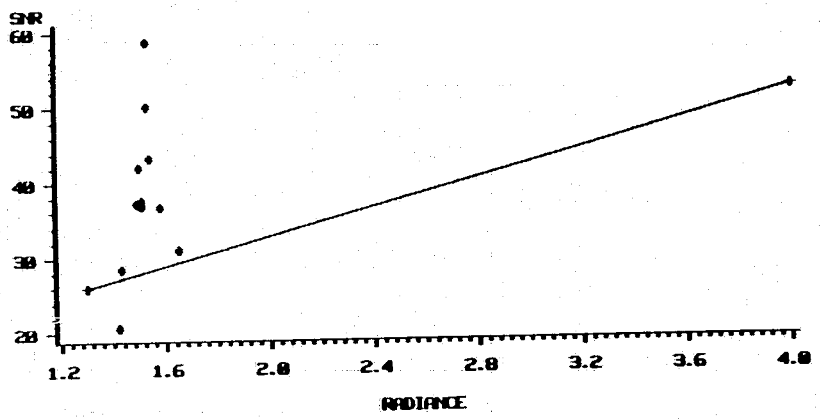
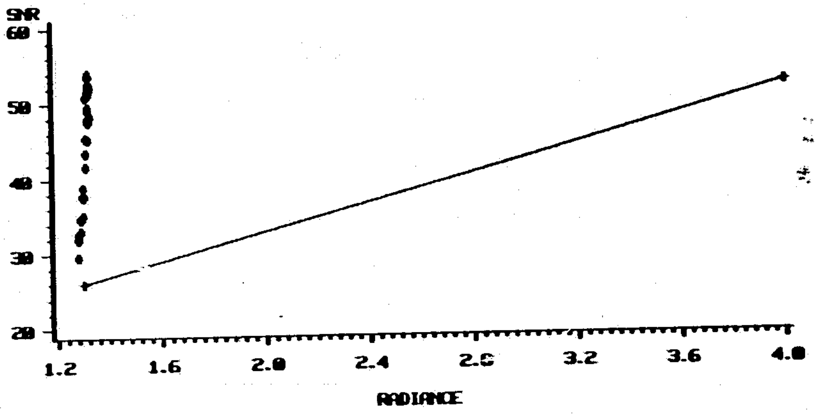
TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND3
SEGMENT 9647



TM SIGNAL TO NOISE RATIO

BY RADIANCE FOR BAND3
SEGMENT 9652



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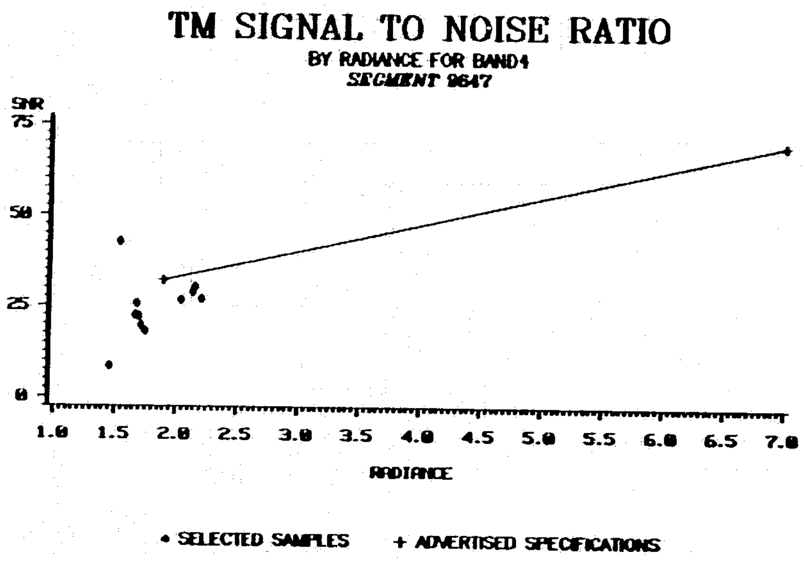
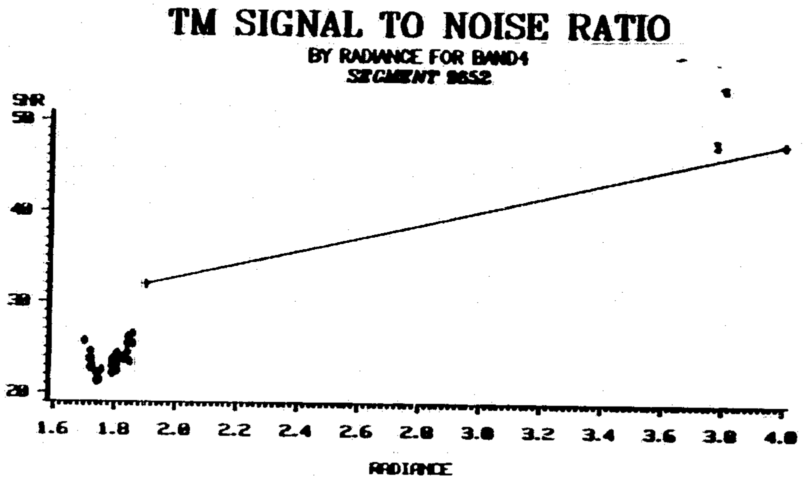


TM SIGNAL TO NOISE RATIO
BY RADIANCE FOR BAND4
SEGMENT 9647



TM SIGNAL TO NOISE RATIO
BY RADIANCE FOR BAND4
SEGMENT 9652

* SELECTED SAMPLES + ADVERTISED SPECIFICATIONS

Higher values for S/N indicate that specifications are being exceeded

- Results:
  - Data
    - Segment 9647 - 12 varying pixel size samples from the water.
    - Segment 9652 - 30 samples, each 20 x 20 pixels.

  - For Both Segments

    Although targets covering the entire possible range were not extracted, the following observations were evident:
    - Bands 1-3 perform much better than specifications.
    - Band 4 perform slightly worse than specifications.
    - Results are in agreement to those seen in preliminary tests[1].

SIGNAL-TO-NOISE RATIO (S/N)				
	MINIMUM SCENE RADIANCE		MAXIMUM SCENE RADIANCE	
BD	SPECIFIED	ACTUAL	SPECIFIED	ACTUAL
1	32	52	85	143
2	35	60	170	279
3	26	48	143	248
4	32	35	240	342

[1] Landsat Data User Notes, Issue No. 23, July 1982.

2.0 STUDIES ILLUSTRATING
POTENTIAL IMPROVEMENTS
DUE TO
INCREASED TM SPATIAL RESOLUTION

2.1 BOUNDARY/MIXED PIXELS USING FIELD FINDING ALGORITHM

- Rationale:

  Current crop inventory technology has traditionally experienced an as-yet-to-be resolved effect from pixels that contain more than one category of interest. Thus, the impact due to the increased spatial resolution of the TM is very important.

- Objective:

  Examine the boundary pixel content of a TM agricultural scene.

- Approach:

  1. Categorize a TM scene by noting the types and relative content of boundary pixels utilizing the current field definition technology.
  2. Comparison of TM and MSS agricultural scene boundary pixel content.

- Output:

  Proportions of boundary pixels in TM and associated MSS (if applicable) scenes.

- Results:

  Segment 231 - TMS-MSS Boundary Pixel Content via the Dennis Field Definition Algorithm.

  MSS - August 6, 1979

  Perimeter boundary - 0.0% of the scene
  Linear boundary - 0.0436% of the scene
  Interior boundary - 0.0% of the scene

  TM - July 20, 1982

  Perimeter boundary - 0.0009% of the scene
  Linear boundary - 0.0160% of the scene
  Interior boundary - 0.0% of the scene

Definitions

Perimeter boundary consists of boundary pixels that are easily associated with a vegetated or non-vegetated field and lie on the perimeter of that field.

Linear boundary consists of boundary pixels that are not readily identified with any field, but tend to lie in a line falling between two fields.

Conclusions

As is indicated above, the TM scene boundary pixel content is approximately 39% of that found within the MSS scene. About 2% of the boundary found within the TM scene (perimeter) is easily assigned to defined fields, leaving the final TM scene boundary pixel content just 37% of that found within the MSS scene. Stated alternatively, the MSS scene has a boundary pixel content that is 2.7 times greater than that of the TM scene.

2.2 PURE PIXEL STUDY

- Rationale:

  Current crop inventory technology has traditionally experienced an as-yet-to-be resolved effect from pixels that contain more than one category of interest. Thus, the impact due to the increased spatial resolution of the TM is very important.

- Objective:

  To manually analyze TMS/TM data to see if it will be an improvement over the MSS boundary pixel problem.

- Approach:

  1. Methodology

     Examine grid intersections of TMS/TM for boundary and pure pixels on an agricultural area, an urban area, and an area with body of water.

- Input Products:

  1. TMS/TM data of agricultural area, Channels 2, 3, 4.
  2. TMS/TM data of urban area, Channels 2, 3, 4.
  3. TMS/TM data of water, Channels 2, 3, 4.

- Output Products:

  Summary Report.

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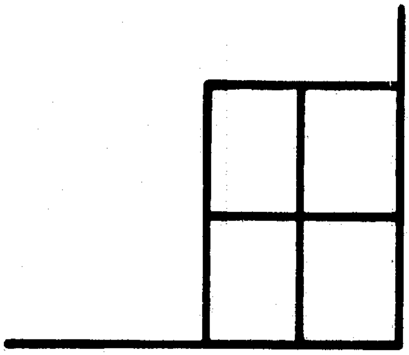
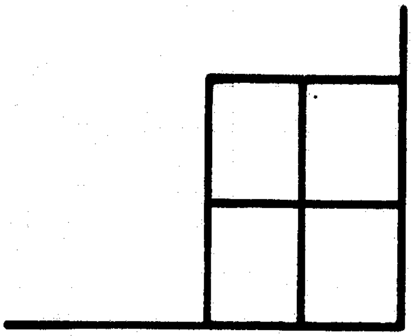
COMPARISON OF TM AND MSS PURITY

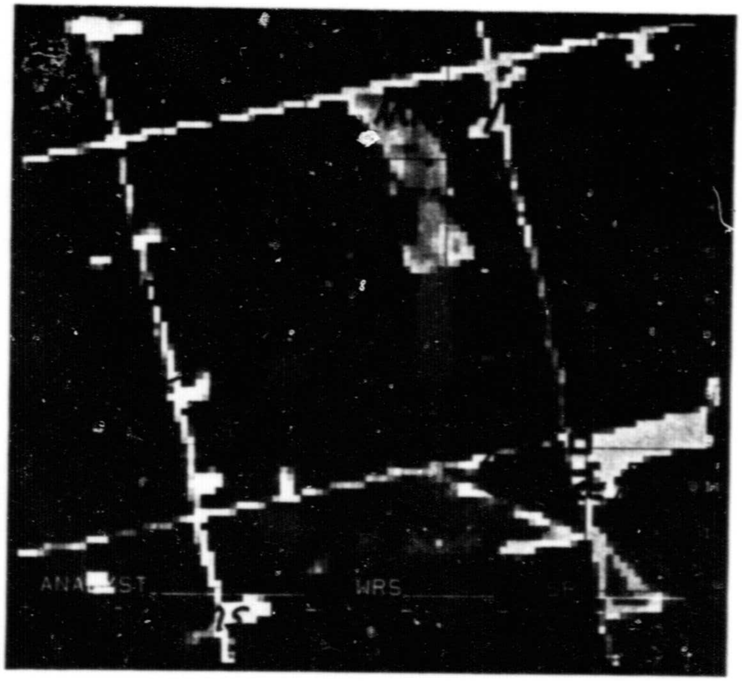


- FROM TM DATA, THIS IS PURE
- FROM MSS DATA, THIS IS PURE

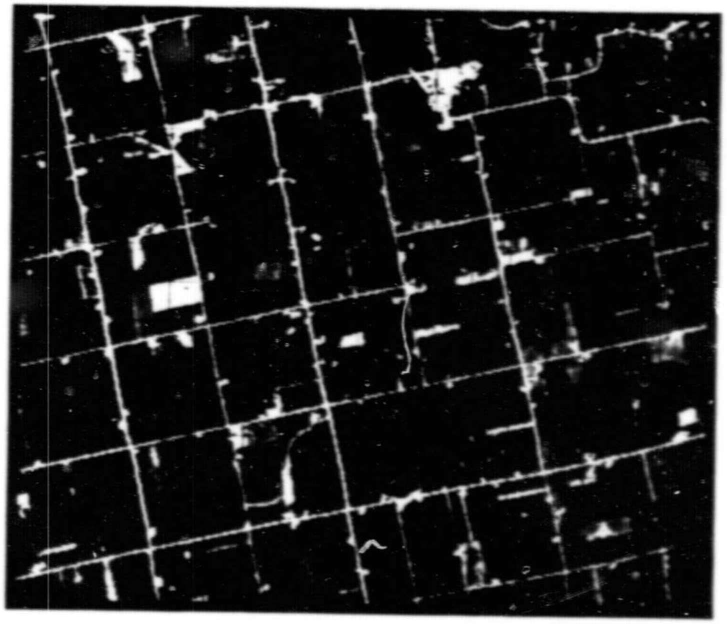


- FROM TM DATA, THIS IS PURE
- FROM MSS DATA, THIS IS MIXED

AN ENLARGEMENT OF THE TOP LEFT-HAND CORNER OF THE TMS SCENE



A TMS SCENE OF WEBSTER COUNTY, IOWA, SEGMENT 893, AUGUST 30, 1979



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SEGMENT # 9645 COUNTY, STATE TECUMSEH, OH

ACQUISITION(S) 79242

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	PURiTY	
																			TM	MSS
10	/M	/M				/M	/M			/M				/M			/M		18/18	11/18
20		/M	/M							M/M	/M	M/M			/M	M/M		/M	15/18	10/18
30		/M				M/M					M/M	/M	/M						16/18	13/18
40																			18/18	18/18
50					/M													M/M	17/18	16/18
60	/M					/M		/M	/M		M/M								17/18	13/18
70			/M				M/M		/M					/M					17/18	14/18
80		/M	/M							M/M				/M	/M	/M	/M		17/18	11/18
90	M/M		/M	M/M	/M		M/M	/M		M/M					/M		/M		14/18	9/18
100	/M			M/M		/M				/M								/M	17/18	13/18
110			/M			/M		M/M	/M	/M	/M	/M							17/18	11/18
120	M/M							/M		/M	/M	/M		/M		/M			17/18	11/18
130	/M		M/M	/M	M/M	/M	M/M			M/M			M/M			M/M		M/M	11/13	8/18
140				/M	/M		M/M	/M						M/M			M/M	M/M	14/18	11/18
150	M/M	/M	/M		M/M	/M		M/M		/M						/M			15/18	10/18
																		TOTALS →	240/270	179/270
																		PERCENT →	88.9	66.3

TM/MSS

A "BLANK" INDICATES "PURE" AN "M" INDICATES "MIXED"

DOT COMPARiSON FORM

SEGMENT # 9646 COUNTY, STATE EAST TOLEDO, OH

ACQUISITION(S) 79242

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	PURITY	
																			TM	MSS
10	/ M				/ M	/ M	/ M			/ M				/ M		/ M	/ M	M / M	17/18	9/18
20	/ M					/ M	/ M		/ M					/ M	/ M				18/18	12/18
30				/ M								/ M	/ M	/ M	/ M	/ M	/ M		18/18	11/18
40		M / M	/ M	/ M	/ M							/ M	M / M	/ M	/ M	/ M	/ M	/ M	16/18	7/18
50	/ M			/ M		/ M					/ M								18/18	14/18
60	/ M						/ M			M / M					/ M			/ M	17/18	13/18
70		M / M	/ M	M / M	M / M	/ M					/ M			/ M	/ M	/ M		/ M	15/18	8/18
80					/ M		M / M	/ M	/ M					/ M		/ M	/ M		17/18	11/18
90	M / M				/ M				M / M				/ M			M / M		M / M	14/18	12/18
100						/ M	/ M			/ M	M / M			M / M	/ M	/ M			16/18	11/18
110		/ M			/ M		/ M						M / M					/ M	17/18	13/18
120				/ M						M / M	/ M								17/18	15/18
130							/ M		/ M	M / M		/ M	M / M		/ M	/ M			16/18	11/18
140						/ M						/ M	M / M		/ M				17/18	14/18
150					M / M	/ M	/ M	/ M		M / M									16/18	13/18
TOTALS →																			249/270	174/270
PERCENT →																			92.2	64.4

A "BLANK" INDICATES "PURE" AN "M" INDICATES "MIXED"

TM / MSS

DOT COMPARISON FORM

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SEGMENT # 9647 COUNTY, STATE SANDUSKY, OH

ACQUISITION(S) 79242

	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	PURITY	
																			TM	MSS
10	/M	M/M				/M	M/M				/M		/M	/M					16/18	11/18
20	/M			/M	/M	/M	M/M				/M			/M					17/18	11/18
30		/M				/M			/M							/M		/M	18/18	13/18
40			/M		/M			/M											18/18	15/18
50			/M		/M	/M									/M				18/18	14/18
60		/M	M/M	/M											/M				17/18	14/18
70	/M	/M																	18/18	16/18
80																			18/18	18/18
90																			18/18	18/18
100																			18/18	18/18
110																			18/18	18/18
120																			18/18	18/18
130							/M												18/18	17/18
140				/M	/M		/M			/M									18/18	14/18
150					/M											/M			18/18	16/18
TOTALS →																			266/270	231/270
PERCENT →																			98.5	85.5

A "BLANK" INDICATES "PURE" AN "M" INDICATES "MIXED"

TM/MSS

DOT COMPARISON FORM

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- Results:

  Three (3) Thematic Mapper (TM) scenes have been manually analyzed to examine grid intersections for boundary (mixed) and pure pixel problems. The results are:

	PURITY	
	TM %	MSS %
9645 Tecumseh, MI	88.9	66.3
9646 East Toledo, OH	92.2	64.4
9647 Sandusky, OH	98.5	85.5

From these results, although a very small sample, an improvement of boundary (mixed) and pure pixel problems can be observed. Further study should be done to substantiate this improvement.

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2.3 SMALL TARGET RECOGNITION

- Objective:

  Illustrate detection of near-pixel-size features on TM imagery. Possible areas of interest and associated features:

  - Country Club (swimming pool, tennis courts, greens, sand traps).
  - Airport (hangers, taxiways, aircraft).
  - University (athletic fields, buildings).
  - Urban Area (new development, shopping mall, park, water tower).
  - Power Plant (transformer yard, fuel storage tanks, cooling tower).
  - Bridges (auto/railroad).
  - Tank Farms, Orchards, Small Islands, etc.

- Results:

  Improved resolution of the Thematic Mapper provides significant additional detail which will improve the performance of analysis techniques in areas where problems have been encountered due to small fields.

ANN ARBOR, MICHIGAN, #9648
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(SCALE OF ENLARGEMENT 1:30,000)

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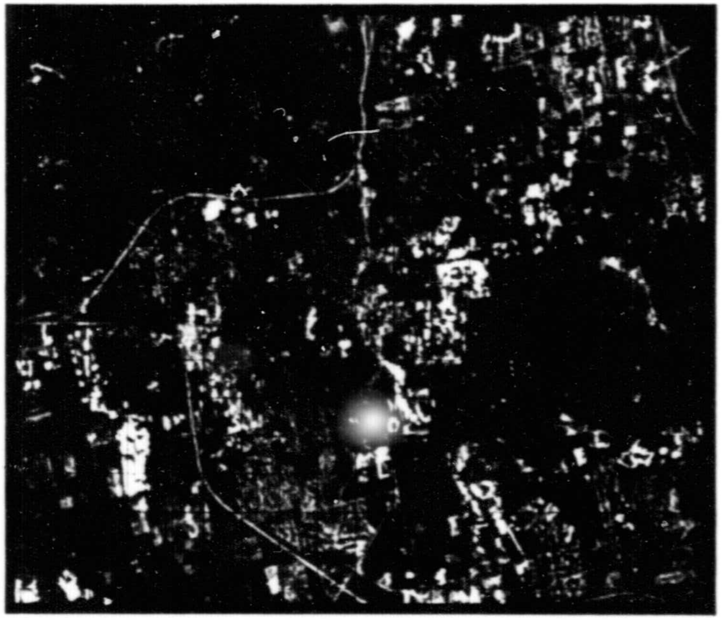
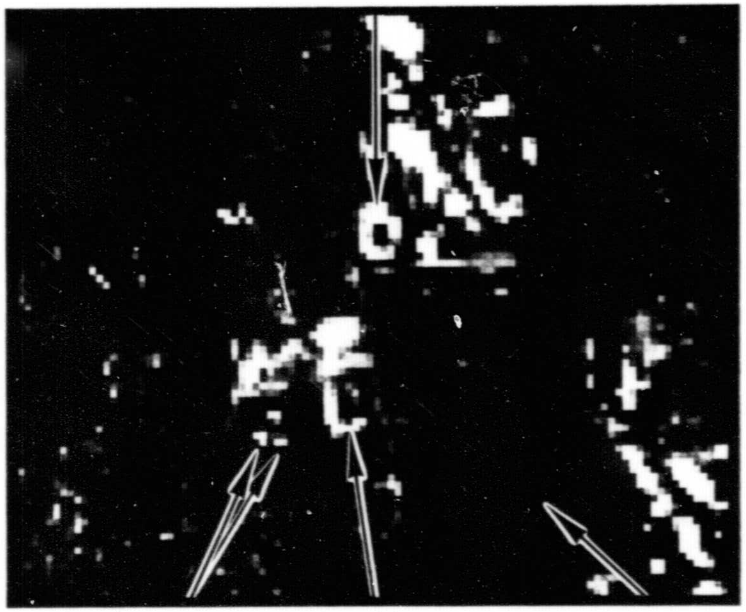


UNIVERSITY OF MICHIGAN
FOOTBALL STADIUM



BASEBALL
DIAMONDS

FOOTBALL FIELD
(60 X 120 METERS)

GOLF COURSE

1:24,000

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DETROIT METROPOLITAN AIRPORT
#9650, SCALE 1:111,000

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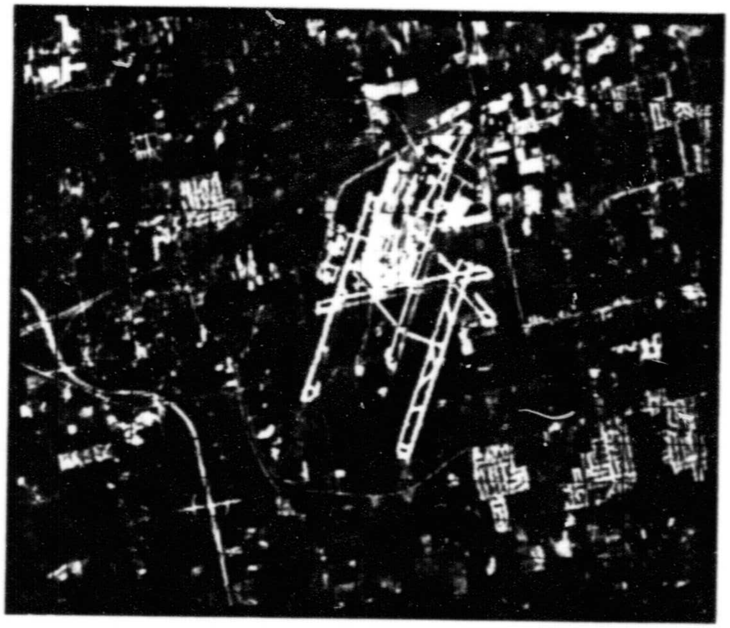
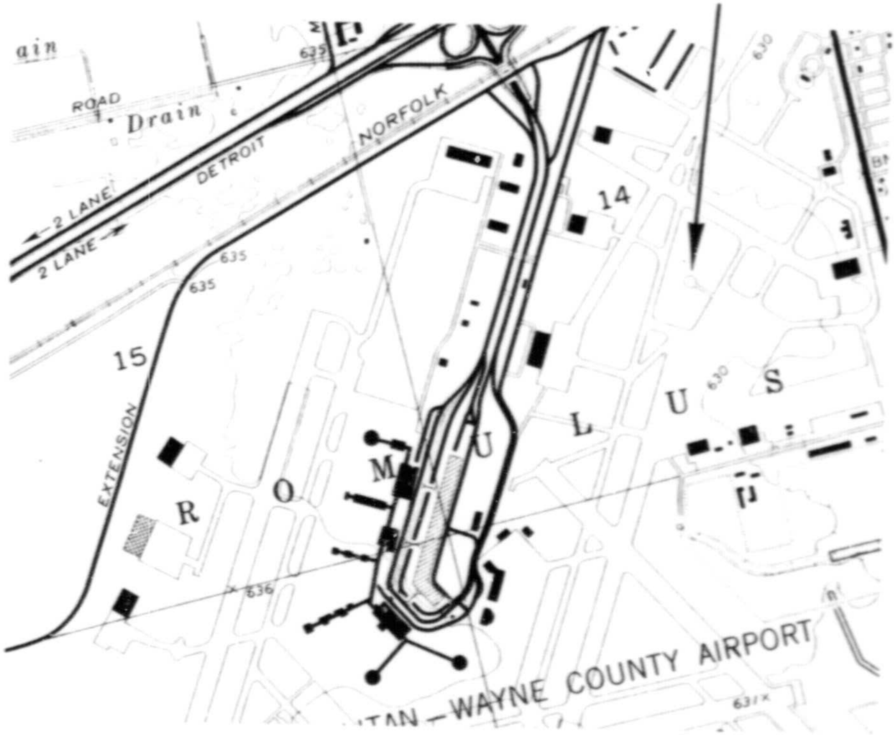


CIRCULAR CONCRETE PAD
(40 METERS IN DIAMETER)
IMAGED AS FOUR TM PIXELS



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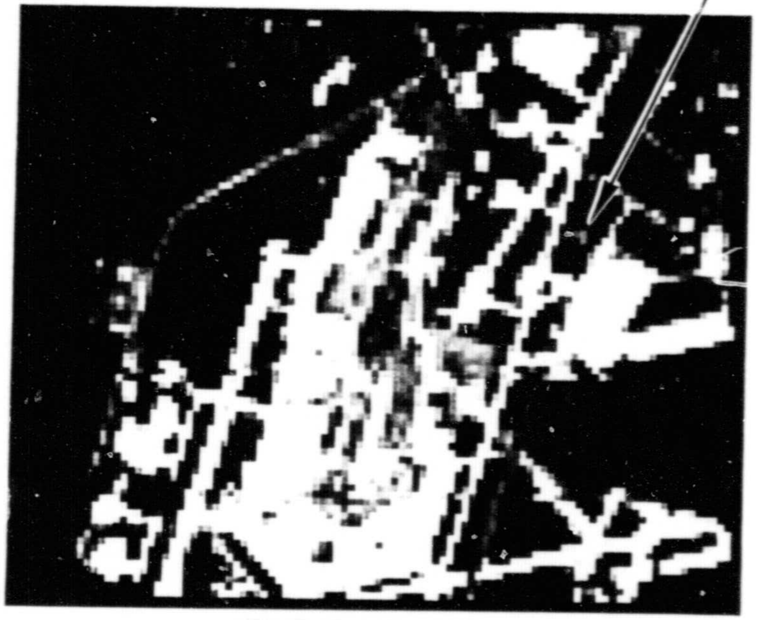

TERMINAL AREA

TOLEDO, OHIO (CENTRAL) #9646
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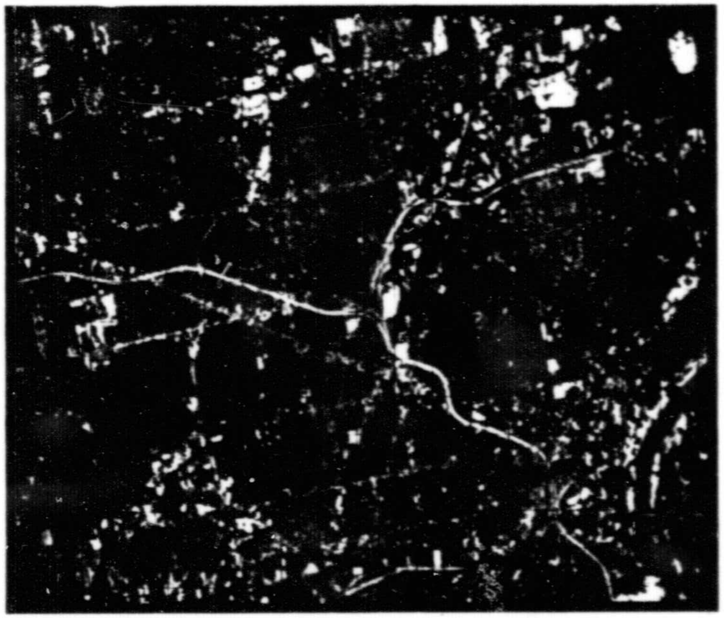

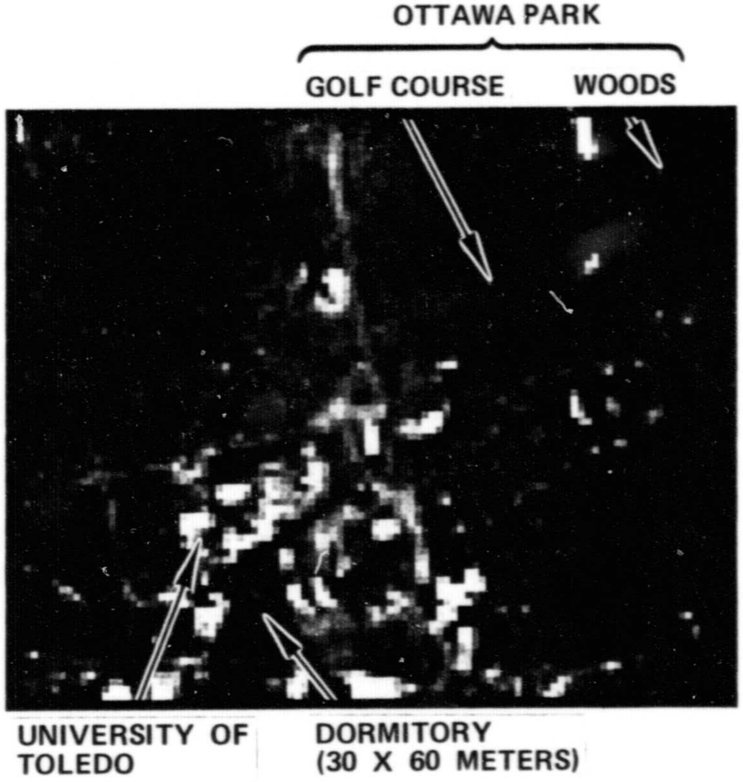

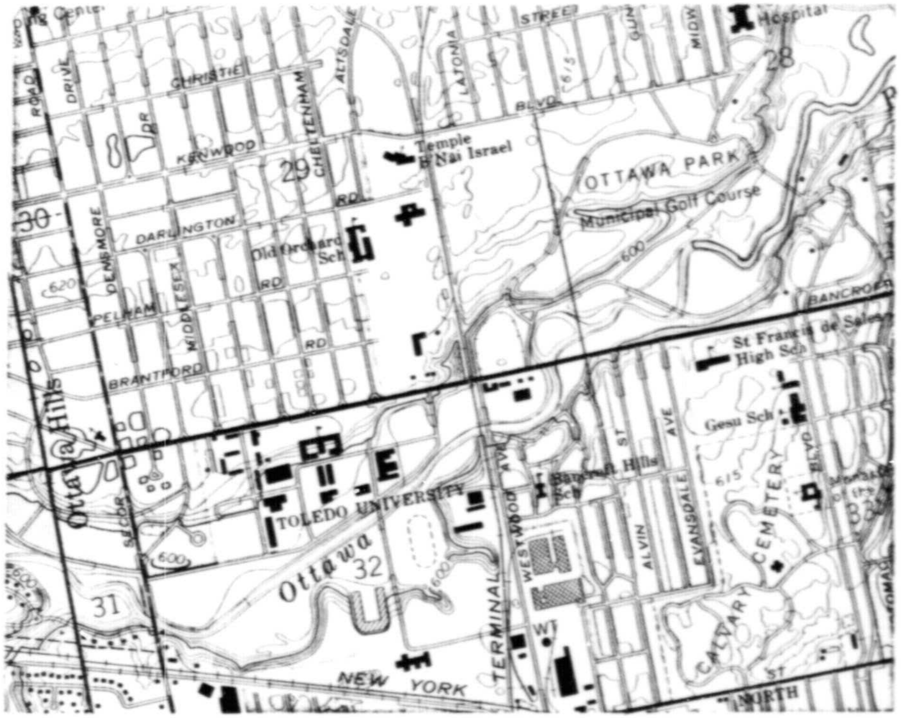

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TOLEDO, OHIO (WEST) #9649
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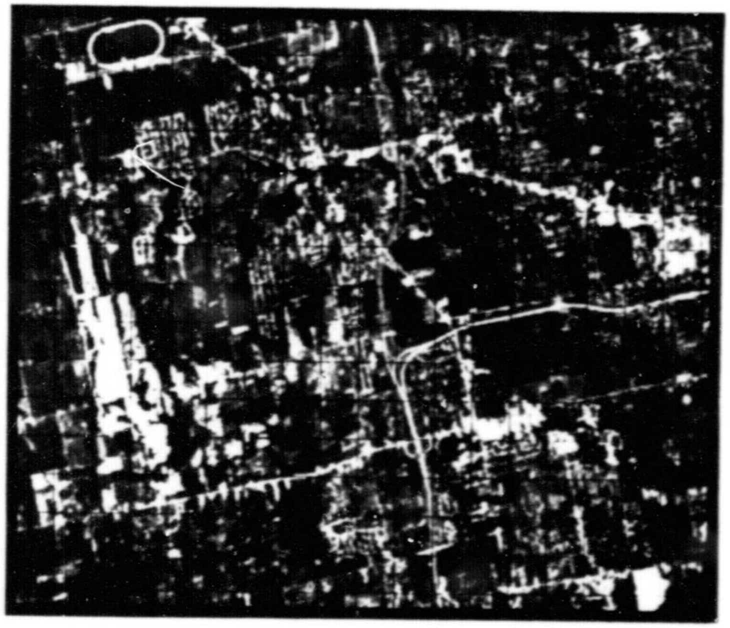

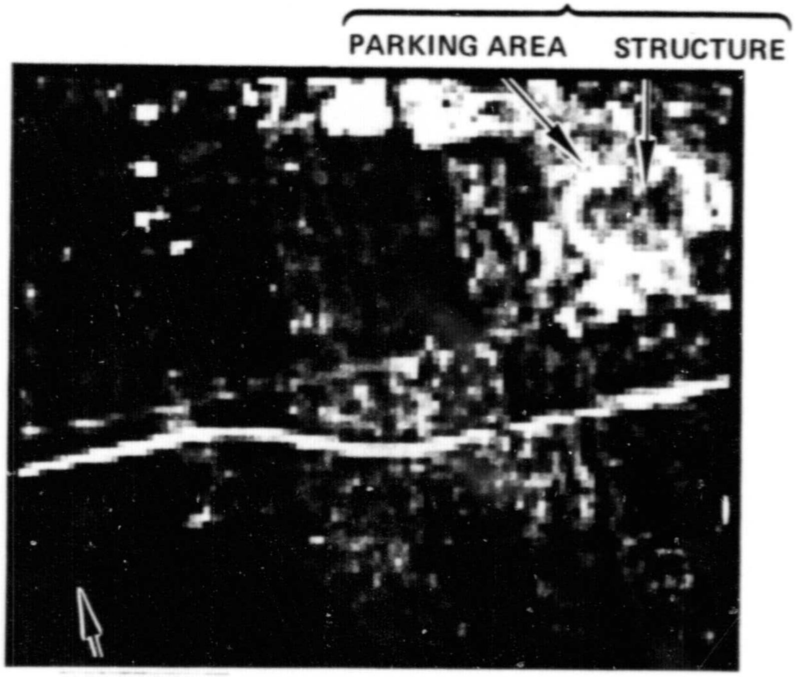

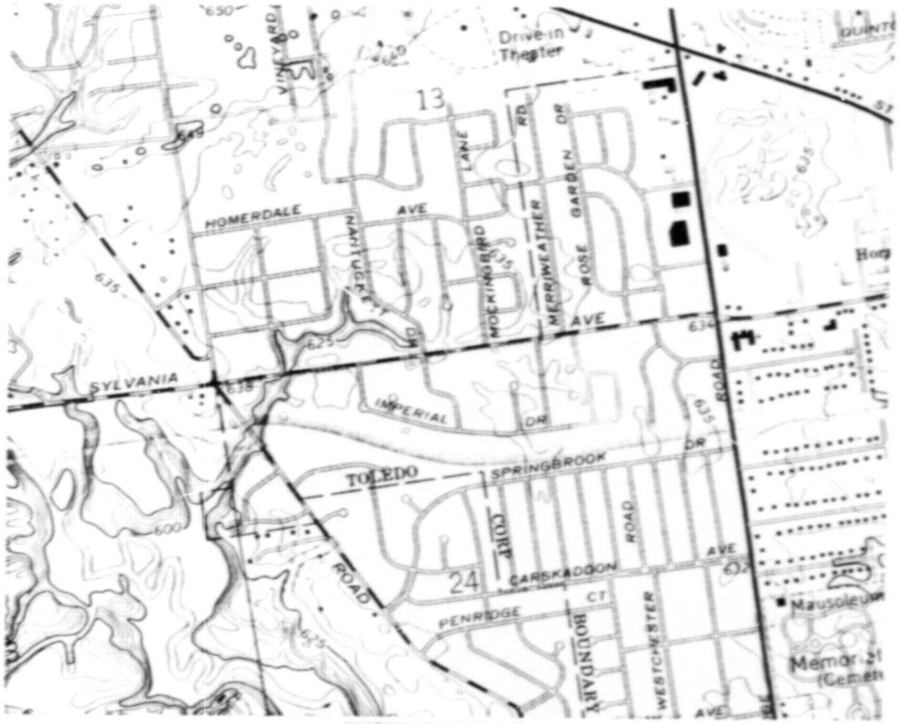

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2.4 EVALUATION OF TM IMAGERY FOR COLLECTING GROUND TRUTH

- Rationale:

  Ground data are essential to technology development activities and are a necessity in evaluating the performance of technology when applied to Landsat data. If a high resolution Thematic Mapper image can be substituted for the aerial photo base presently used, it will be more timely and cost effective in collection of the ground data.

- Objective:

  Evaluate the suitability of the "high resolution" Thematic Mapper image as a substitute for the aerial photo ground truth base.

- Scope:

  Evaluate one TM segment size image in the "Quick Look" in late August or early September, dependent on data availability.

- Approach:

  Data preparation/input products

  A TM segment from the Detroit/Toledo July 20, 1982 scene was selected for ground data collection. The site chosen was segment 9645 in the Clinton-Tecumseh, Michigan, area. The site is a mixture of agriculture and urban area with rolling terrain.

  The geographic center coordinates for segment 9645 were estimated using previous MSS Landsat data. These coordinates were then used to obtain a 1:24,000 scale topographic map and to order Return Beam Vidicon (RBV) imagery. (June 14, 1982, acquisition date).

  A data search for archived aerial photography was conducted. No recent aerial photography was readily available of the area of interest.

  Due to scheduling constraints a decision was made to start the ground data collection using the RBV 1:24,000-scale image enlargement.

Data collection

Field work began on September 13, 1982, using the RBV enlargement. The next day the 1:24,000 scale TM segment area image base was received. The TM enlarged photo base was used for the ground data collection activity for the remainder of the week.

- Output Products/Results:

All accessible areas of the segment (80-85%) were inventoried and recorded on the Thematic Mapper photo base. The output products are the field inventory recorded on the TM base, field comments, and 35 mm. Slides for a representative subset of the segment area.

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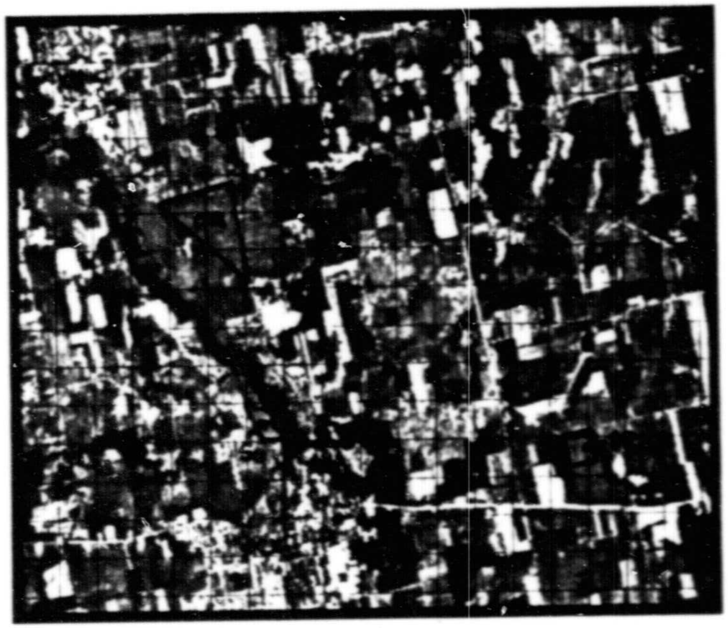

SUMMARY:

THEMATIC MAPPER PRODUCTS WERE SENT TO THE FIELD FOR GROUND TRUTH COLLECTION FOR THE TM EVALUATION STUDIES.

A GROUND DATA INVENTORY FOR SEGMENT 9645, COVERING THE CLINTON-TECUMSEH, MICHIGAN AREA, WAS MADE USING A 1:24,000 SCALE THEMATIC MAPPER IMAGE AS A COLLECTION BASE. THE SITE WAS A MIXTURE OF AGRICULTURE AND URBAN AREA WITH A ROLLING TERRAIN. FIELD SIZE RANGED FROM 160 ACRES TO ONE ACRE, RECTANGULAR TO IRREGULARLY SHAPED. THE PREDOMINANT CROP TYPES WERE CORN, SOYBEANS, AND WINTER WHEAT. THE BALANCE OF THE FARMLAND WAS IN OATS, ALFALFA, PASTURE, AND SPECIALITY CROPS. ALL ACCESSIBLE AREAS OF THE SEGMENT WERE INVENTORIED (80-95%) OF THE SEGMENT). FIELD COMMENTS AND SLIDES WERE MADE FOR A REPRESENTATIVE SUBSET OF THE SEGMENT AREA.

3.0 STUDIES ILLUSTRATING INCREASED INFORMATION FROM IMPROVED TM BAND PLACEMENT AND SELECTION

3.1 TM BAND/COMPOSITE USEFULNESS LIGHT-TABLE STUDY

- Objectives

  1. To identify the usefulness of the individual bands in discerning land use characteristics and assessing environmental conditions.
  2. To identify band composites that may further aid in discriminating land use features and environmental phenomena.

- Approach:

  1. Determine the principal applications of each band through analysis of available literature.
  2. Select segments having varieties of land use and environmental conditions.
  3. Examine the individual bands for discrimination of the above.
  4. Through analysis of the seven bands, select composites which may further aid in condition assessment and land use classification.

- Outputs:

  - Qualitative summary of the overall usefulness of each band and selected composites.

- Results:

  - The results of this band/composite analysis are shown in the figures of this section.

3.1.1 LAND USE/CROP IDENTIFICATION CAPABILITY AND USEFULNESS OF BANDS/BAND COMPOSITE

BAND USEFULNESS:
A LITERATURE COMPOSITE

Band	Spectral Range: um	Principal Applications
1	0.45 to 0.52	Coastal water mapping, soil/vegetation differentiation, and diciduous/coniferous differentiation.
2	0.52 to 0.60	Green reflectance peak of vegetation between 2 chlorophyll absorption bands; vegetation discrimination and vigor assessment.
3	0.63 to 0.69	Most important band for vegetation discrimination; chlorophyll absorption region for vegetation/nonvegetation discrimination, and contrasts within vegetation classes.
4	0.76 to 0.90	Biomass surveys and will aid in crop identification and emphasize soil/crop contrasts.
5	1.55 to 1.75	Important for crop type, crop water content, and soil moisture studies.
6	10.4 to 12.5	Vegetation classification, vegetation stress analyses, soil moisture discrimination, and other thermal related mapping.
7	2.08 to 2.35	Important in the discrimination of rock type and for hydro-thermal mapping.

BAND USEFULNESS
BAND BY BAND ANALYSIS AS OBSERVED FROM TMS

Band 1	Soil-vegetation separation (urban areas, roads, and harvested fields): field separation is poor; minor forest discrimination.
Band 2	Vegetation separation, corn from soybeans from natural; some stage separation between fields. Harvested areas are difficult to observe. City and roads are distinct, however, their contrast is better in Band 1.
Band 3	No discrimination between vegetation classes; vegetated and non-vegetated distinction (urban area, roads, and harvested areas versus general vegetation).
Band 4	General vegetation separation, corn from soybeans from forest; texturing occuring in forest. City trees may be dominating causing the urban area to resemble the natural areas; harvested fields are distinct, water is observable but confused with low vegetation patterns.
Band 5	Crop types showing up well, as are the natural vegetation and urban areas. Crop stage separation is observable; ponds/wet areas very distinct; possible soil moisture patterns. Harvested fields are apparent, but discrimination not as apparent as with Band 4.
Band 6	Cannot tell city from harvested regions. Warmer areas are apparent, vegetated/nonvegetated regions discernible.
Band 7	Urban and harvested areas are apparent, as are roads and forests; vegetation discrimination possible; stripping is occuring in image.

SINGLE-BAND ANALYSIS OF TM SITES, LAKE ST. CLAIR CANADA, SEGMENT 9651

BAND 1

SHARP LAND/WATER CONTRASTS. IN LAKE ST. CLAIR ARE OBSERVED VARIOUS DIFFERENCES IN REFLECTANCE APPROXIMATELY 1 MILE OFFSHORE AND NEARSHORE. DIFFERENCES APPARENTLY DUE TO DEPTH AND INCREASING TURBIDITY DOWNCURRENT OF CREEK MOUTH.

OBSERVABLE DISTINCTION BETWEEN SOIL, HARVESTED FIELDS AND SUMMER CROPS. BARE SOIL APPEARS BRIGHT WHITE, SUMMER CROPS VERY DARK WITH THE HARVESTED FIELDS VARYING SHADES OF GRAY. NO APPARENT DISTINCTION BETWEEN SUMMER CROPS. NONVEGETATED AREAS SUCH AS ROADS AND FARMSTEADS STAND OUT, BEING LIGHT SHADES OF GRAY.

BAND 2

IN THE WATER BODY, NEARSHORE REFLECTANCE IS BRIGHTER THAN FOR BAND 1, WHILE OFFSHORE REFLECTANCE DECREASES. CHANGES MAY BE DUE TO TURBIDITY, AS IS EVIDENCED BY INCREASED REFLECTANCE DOWNCURRENT OF CREEK MOUTH.

VEGETATION AND NON-VEGETATION PATTERNS ARE SIMILAR TO BAND 1.

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SINGLE-BAND ANALYSIS OF TM SITES, TOLEDO, OHIO, SEGMENT 9649

BAND 3

DISTINCT VEGETATION/NON-VEGETATION CONTRASTS AS IS EVIDENT IN THE BRIGHT WHITE QUARRY AND TEST TRACK VERSUS THE VERY DARK VEGETATED AREAS. MOST RESIDENTIAL STREETS AND MAJOR ARTERIES ARE EASILY DISCERNIBLE, WHILE REGIONS OF NATURAL AND CULTURAL VEGETATION ARE CONFUSED'

BAND 4

VEGETATED AREAS APPEAR AS VARIOUS SHADES OF GRAY TO WHITE WHILE WATER AND NON-VEGETATED REGIONS APPEAR DARK GRAY TO BLACK. OBSERVABLE CONTRASTS BETWEEN THE FIELDS OF SUMMER CROPS (EXTREME WEST).

RESIDENTIAL STREETS ARE NOT AS APPARENT AS WITH BAND 3; HOWEVER, TEXTURING OF THE NATURAL VEGETATION IS OBSERVABLE. NOTE DETAIL OF GOLF COURSES, THE OBVIOUS FAIRWAY PATTERNS.

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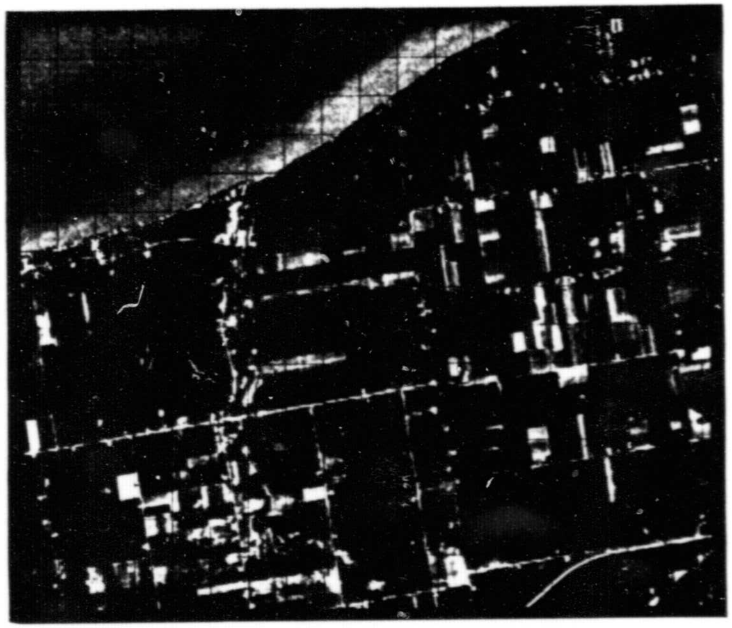
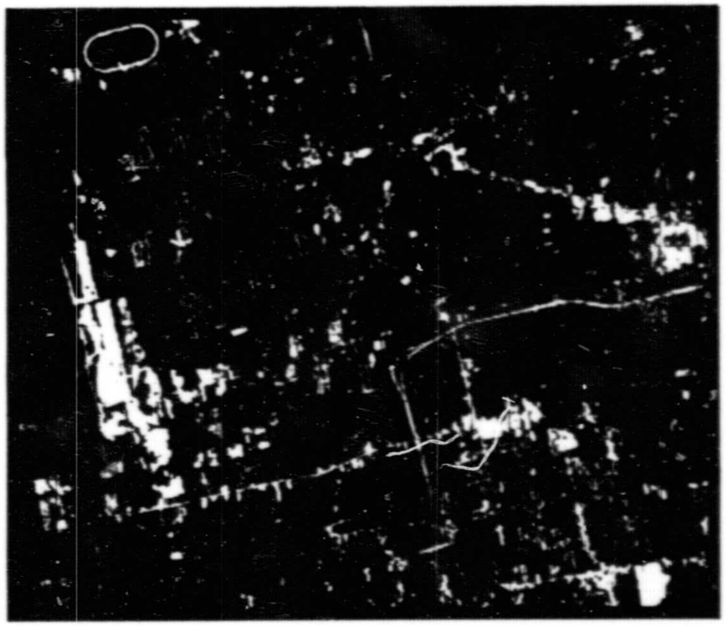
COMPOSITE STUDY OF TM SITES
COMPOSITE 1, 2, 3

LAKE ST. CLAIR, CANADA
SEGMENT #9651



COLOR CONTRASTS IN THE LAKE ARE READILY APPARENT. DIFFERENCES MAY BE DUE TO THE INFLUENCE OF TURBIDITY AND/OR DEPTH. FIELD DEFINITION IS GOOD AS IS THE CONTRAST BETWEEN THE HARVESTED (LIGHTER GRAY) AND VEGETATED (BROWN) FIELDS AND BARE SOIL (WHITE). NO APPARENT DISTINCTION BETWEEN SUMMER CROPS. STREAM PATTERNS AND ROADS ARE READILY OBSERVED. SOME VARIATION IN THE FIELD MOISTURE PATTERNS MAY BE SEEN.

TOLEDO, OHIO
SEGMENT #9649



THE BRIGHT GRAY TO WHITE LIMESTONE QUARRY (FAR LEFT), PAVED AREAS AND BARE SOIL (LOWER RIGHT) ARE READILY APPARENT. RESIDENTIAL STREETS STAND OUT WELL, AS DO THE HEAVILY WOODED PARKS (RIGHT-CENTER). CROPLANDS IN THIS IMAGE TEND TO BLEND TOGETHER.

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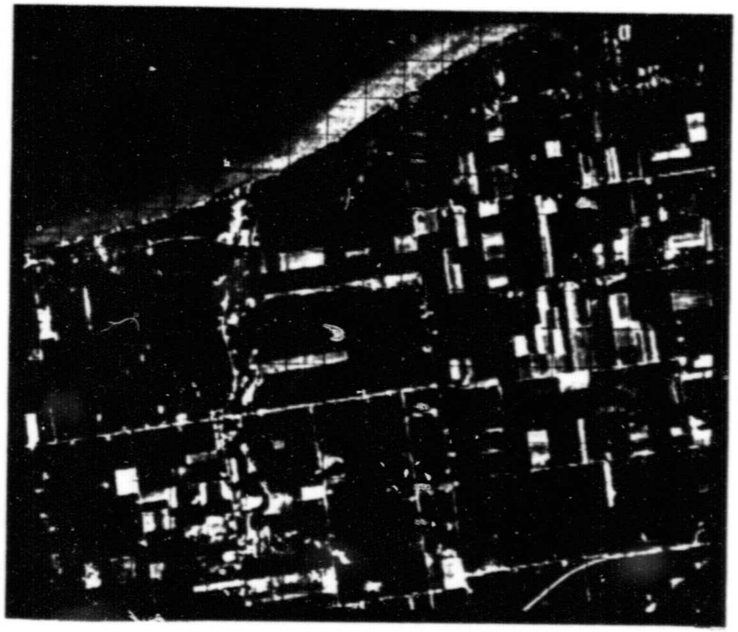
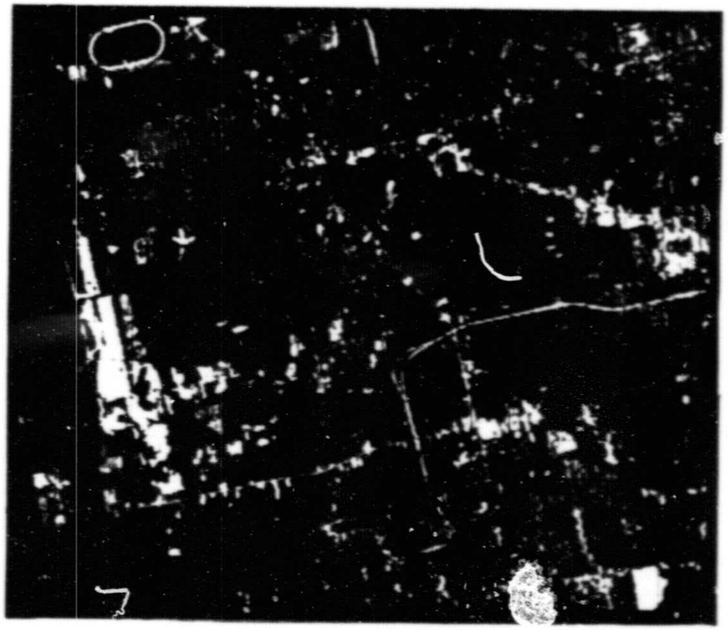
COMPOSITE STUDY OF TM SITES
(COMPOSITE 2, 3, 4)

LAKE ST. CLAIR, CANADA
SEGMENT #9651



TURBIDITY, RATHER THAN DEPTH SEEMS MORE APPARENT. GOOD LAND/WATER CONTRASTS. GOOD DISTINCTION BETWEEN SUMMER CROPS (BRIGHT AND DARK RED) AND HARVESTED (REDDISH-GRAY) FIELDS. ROADS, STREAMS AND FIELD BOUNDARIES ARE WELL-DEFINED.

TOLEDO, OHIO
SEGMENT #9649



NOTE FAIRWAY PATTERNS OF GOLF COURSES, TEXTURING OF THE NATURAL VEGETATION (WOODLOTS), AND THE CONTRASTS BETWEEN THE SUMMER CROPS (FAR LEFT).

AGAIN, QUARRY (EXTREME LEFT), BARE SOIL, ROADS, AND PAVED AREAS (FAR RIGHT) ARE EASILY OBSERVED.

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3.2 AUTOMATED CLASSIFICATION: VISIBLE/IR COMPARISON

3.2.1 THEMATIC MAPPER STUDY

- Rationale:

  New spectral coverage and spatial resolution provided by the Thematic Mapper are expected to allow greater field definition and classification detail and accuracy.

- Objective:

  To identify and qualitatively describe the additional information made available by the TM.

  To evaluate the usefulness of current automated "Spatial Color Sequence" technology as a tool to process this information.

- Approach:

  The "Tecumseh" TM segment (9645) acquisition of July 20, 1982 was processed through Spatial Color Sequence software twice.

  - The first processing was done using TM band 2, 3, 4 to provide a spectral equivalent to MSS coverage.
  - The second processing was done using TM Band 2, 3, 4 and 1, 2, 3 to demonstrate the effect of visible color information.

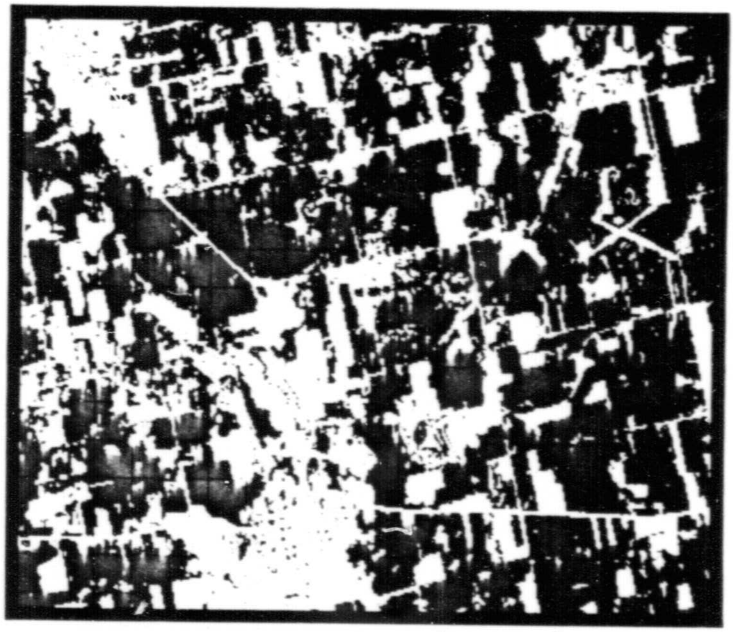
The "Lake St. Clair" TM segment (9651) acquisition of July 20, 1982 was processed through the Spatial Color Sequence software using TM bands 1, 2, 3 to demonstrate the usefulness of visible color information.

The differences in field definition and classification detail obtained from each processing were then analyzed.

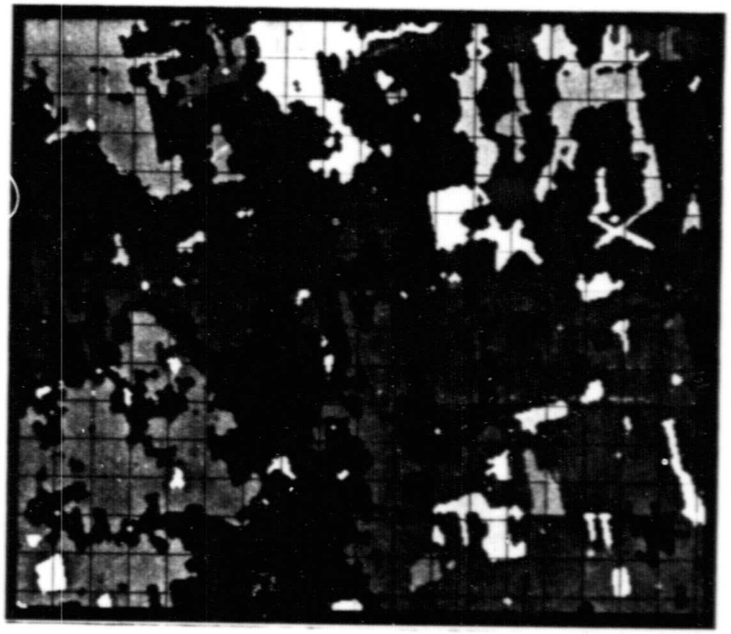
- Results:

  - TM provided greater field definition, as expected, especially when all 4 available Bands were used.

- The increased spectral coverage provided by the use of all 4 available TM bands exhibited apparent improvement in the overall class separability.
- All TM results are consistent with expectations formed during TMS studies. Hence, we expect more "timely" TM acquisitions to provide even more dramatic increases in classification detail and accuracy in agricultural areas.



1. "RED/NON-RED" ("VEGETATED/ NON-VEGETATED") MAP OF BANDS 2, 3, AND 4; TM SEGMENT 9645; TECUMSEH, MI, JULY 20, 1982.



2. LABELING TARGETS OR "FIELDS" DEFINED USING TM BANDS 2, 3, AND 4; SEGMENT 9645; TECUMSEH, MI, JULY 20, 1982.

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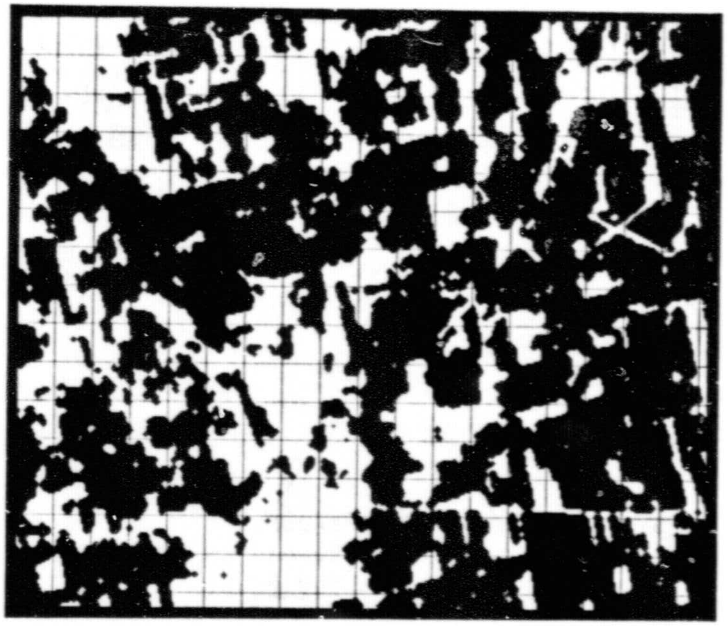

3. CLASSIFICATION MAP OF TECUMSEH, MI. AUTOMATICALLY GENERATED FROM TM BANDS 2, 3, AND 4.

BROWN = HEALTHY VEGETATION, DENSE (SUMMER CROPS, TREES)

GREEN = URBAN/WATER/HARVESTED OR RIPENED FIELDS (SPRING GRAINS)

ORANGE }
YELLOW } "LESS DENSE" VEGETATION

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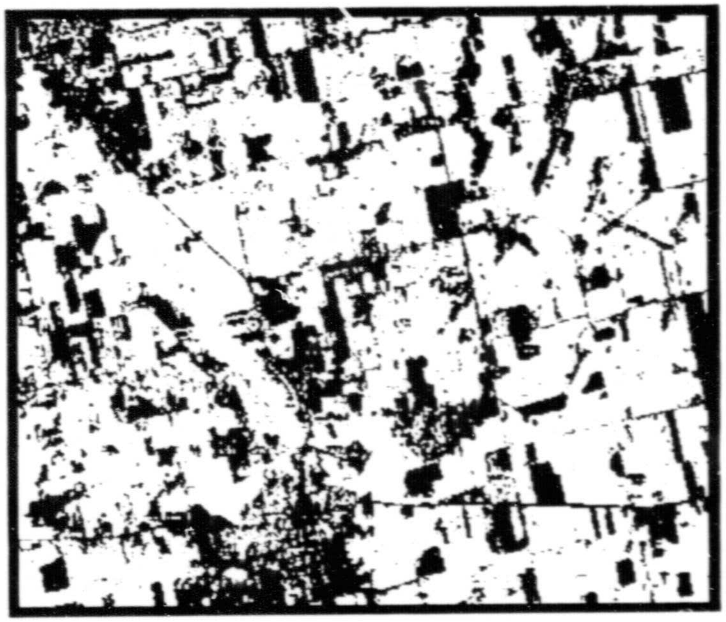
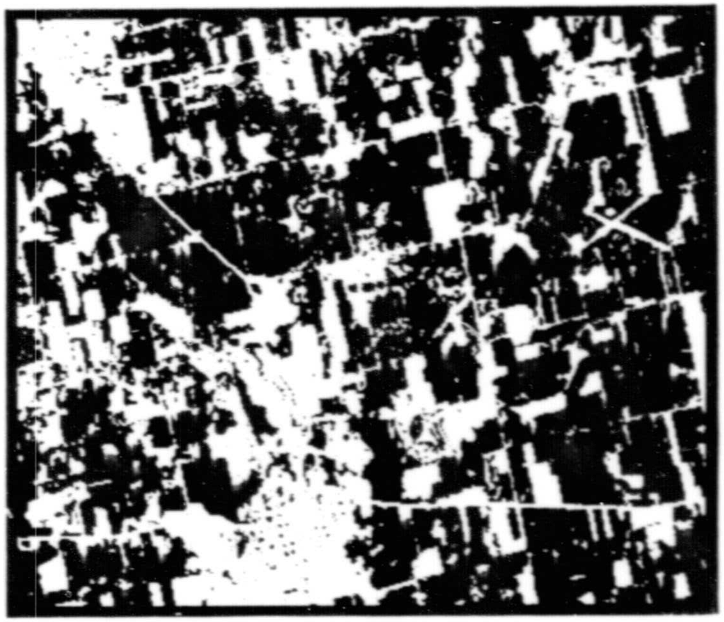


4. "RED/NON-RED" MAP OF BANDS 1, 2, AND 3. TM SEGMENT 9645, TECUMSEH, MI, JULY 20, 1982.



5. "RED/NON-RED" MAP OF BANDS 2, 3, AND 4. TM SEGMENT 9645, TECUMSEH, MI, JULY 20, 1982.

THESE TWO MAPS ARE COMBINED TO PROVIDE "FIELDS" WHICH ARE USED AS LABELING TARGETS.

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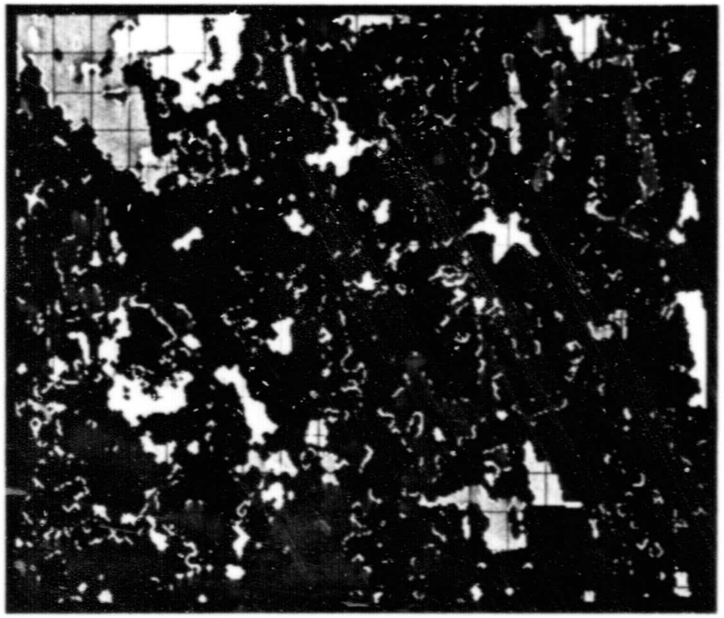
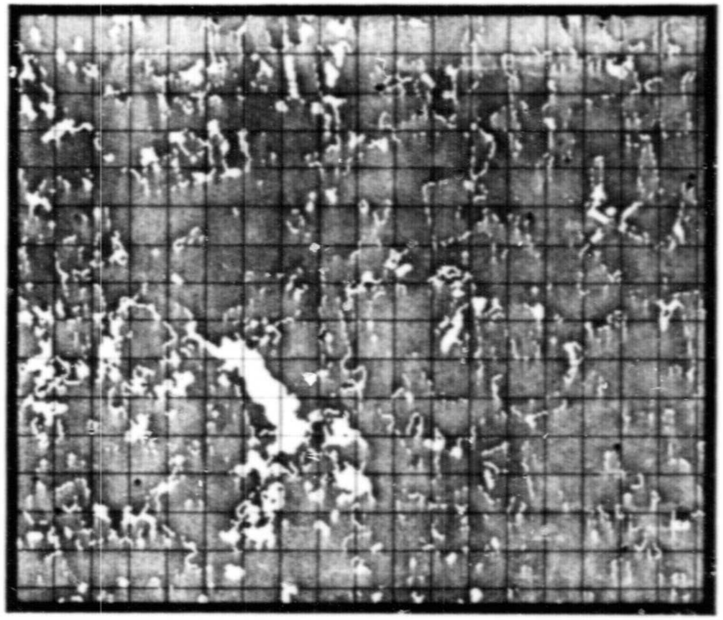


6. "FIELDS" DEFINED USING TM BANDS 1, 2, 3, AND 4. SEGMENT 9645, TECUMSEH, MI, JULY 20, 1982.



7. CLASSIFICATION MAP AUTOMATICALLY GENERATED FROM TM BANDS 1, 2, 3, AND 4. TECUMSEH, MI, JULY 20, 1982.

BLUE = WATER AND WET AREAS
YELLOW = URBAN/HARVESTED AND RIPE FIELDS (SPRING GRAINS)
GREEN = HEALTHY DENSE VEGETATION (SUMMER CROPS, FOREST)

NOTE THE LARGE BODY OF WATER IN THE LOWER LEFT PORTION OF THE SCENE.

THE INCORPORATION OF BAND 1 DATA PERMITS THE CORRECT CLASSIFICATION OF SUCH AREAS.

- Comments on results of running automated field-finding algorithm on segment 9651 (Canadian scene including portion of Lake St. Clair).

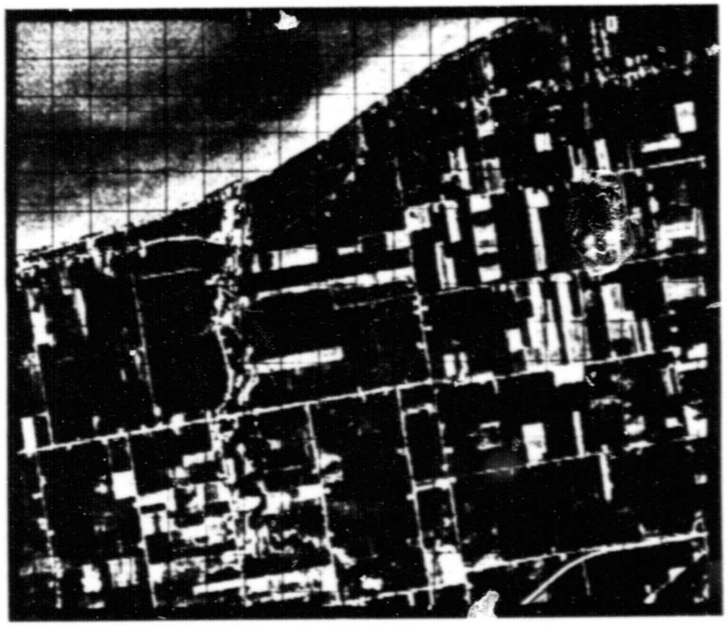
  - Agricultural portion shows same limited variability observed in other July 20 segments. However, the larger areas of water is divided into "fields" with three distinct signatures. These correspond to the yellow-green-blue zonation along the coastline observable in the film product.

  - This observation suggests that the visible signature variability noted in the TMS data is also present in the TM data. When acquisitions are obtained later in the year, this signature variability can be expected to prove useful for crop type identification and crop condition assessment. In other words, this segment provides further evidence that the TMS data gave a good approximation of TM capabilities.

  - This demonstration of water signature discriminability may have significance for disciplines other than agriculture. For example, oceanographers, ecologists, and environmentalists all are actively seeking a means of quantifying visible color differences in water bodies so as to measure plankton, chlorophyll and pollution levels. It is possible that the automated technology developed for agricultural use with color infra-red imagery may be applicable to water studies in the visible spectrum as well. In any event, the addition of the blue band appears to have added considerably to TM usefulness, and this will be further enhanced by the ability to relate the observations to standard U.S. color nomenclature (National Bureau of Standards (NBS)/Munsell).

  - The TM discrimination of color differences is particularly remarkable since on a scale of 0-9 these colors have an intensity (or saturation or purity or chroma) of less than one. Thus, TM is distinguishing colors at or below the threshold of human detectability.

9651 123



LAKE ST. CLAIR, CANADA. THIS COMPOSITE OF TM BANDS 1, 2, AND 3 SHOWS DIFFERENCES IN WATER COLOR WHICH ARE NOT AS APPARENT IN THE COMPOSITE OF TM BANDS 2, 3, AND 4.

9651 234

LAKE ST. CLAIR, CANADA. THIS IMAGE IS A COMPOSITE OF DATA IN TM BANDS 2, 3, AND 4.

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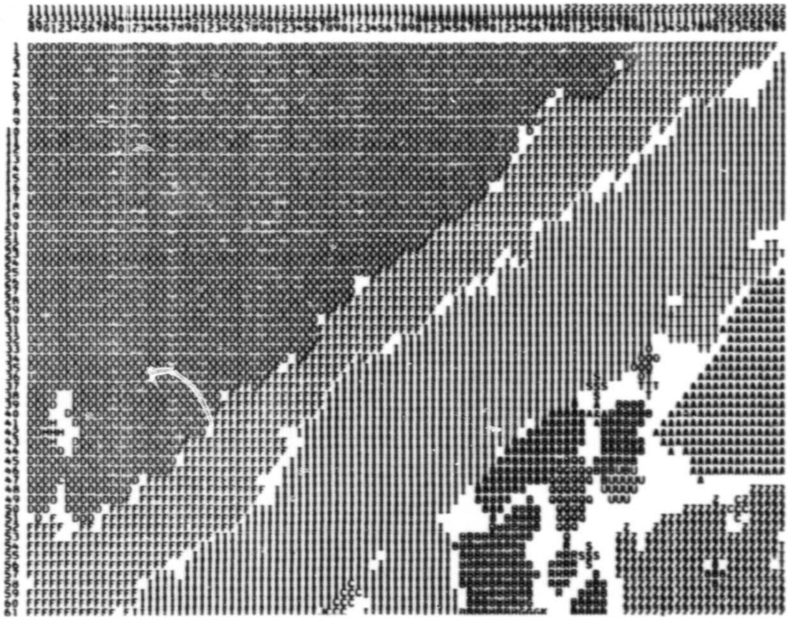
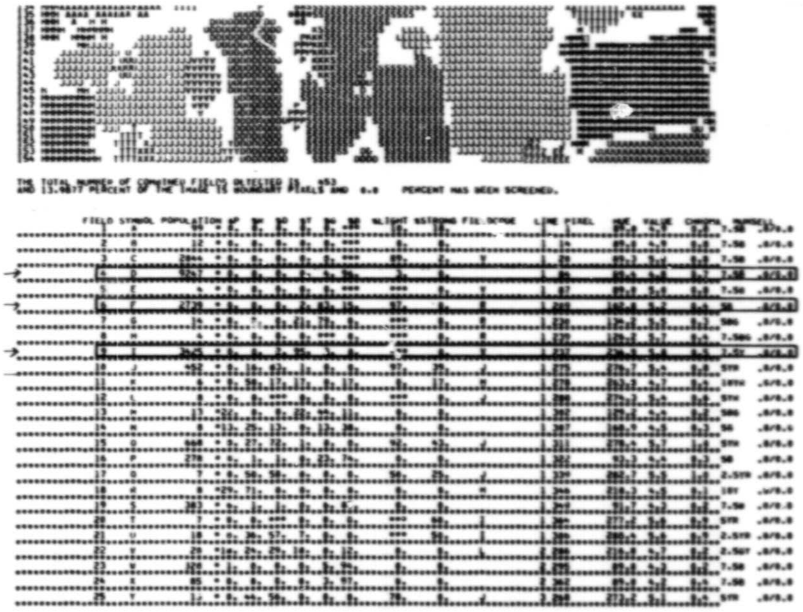


GREY MAP OF THE UPPER PORTION OF THE MIDDLE THIRD OF THE LAKE ST. CLAIR SEGMENT. FIELDS LABELED D, F, AND I ARE THE THREE COLORS OF WATER DISTINGUISHED BY THE AUTOMATED CLASSIFICATION OF TM BANDS 1, 2, AND 3.



THIS PORTION OF THE CLASSIFICATION PRINT-OUT SHOWS THE PERCENTAGE OF EACH FIELD IN EACH HUE, VALUE, AND CHROMA AS DEFINED BY THE PROCEDURE AND TRANSLATED INTO MUNSELL COLOR.

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3.2.2 SIMULATED THEMATIC MAPPER FEATURE IDENTIFICATION STUDY

- Rationale:

  New spectral coverage and spatial resolution provided by the TM are expected to allow greater labeling target ("field") definition and classification of

- Objectives:

  - To identify and qualitatively describe the additional information made available by the TM.
  - To evaluate the usefulness of current automated "Spatial Color Sequence" vegetation classification technology as a tool to process this information.

- Approach:

  TMS segment (1979 Webster, Iowa) was processed through the Spatial Color Sequence software using the following combinations of Band sets:

  2, 3, 4 alone (as MSS "equivalent")
  2, 3, 4 and 1, 2, 3
  2, 3, 4 and 2, 3, 5
  2, 3, 4 and 2, 3, 6
  2, 3, 4 and 2, 3, 7

Analyze differences in field definition and classification detail obtained with each set.

- Results:

  The field patterns produced from the MSS "equivalent" (234/234) processing and from each of the other four band set combinations were much better correlated with the ground truth field patterns than the field patterns produced by actual MSS processing. (The actual MSS/SCS field patterns and the TMS/SCS fields are shown in Figs. A and B, ground truth map is shown in Figure C. This is presumed to be the result of the greatrer spatial resolution of the TMS data. The improvement in field definition by the addition of each TMS band was analyzed both before and after classification. The improvement in classification detail attributed to better "field" definition is visible in Figures D and E where the MSS based classification is compared to the MSS "equivalent" classification. The results of this analysis follow:

When band 1 (.45 - .52 μ) data is added to bands 2, 3, and 4 the new field definition separated fields of corn from adjacent fields of soybeans and from other fields of corn (fig. F). These areas were interpreted to be later maturing corn fields or corn fields of a different variety than the others (unfortunately, ground truth 9-day observations were not made on many of these fields, so ground observation confirmation of this interpretation was not available). These fields of "late corn" were separated from the soybeans, oats, hay, and natural vegetation areas quite successfully, as were the other corn fields (fig. G). Soybean areas were uniformly and accurately treated by the classifier.

When band 5 (.52 - .60 μ) data was added to bands 2, 3, and 4 field definition was as good as or better than that obtained with band 1. The same "late corn" areas were identified as distinct fields, and the classifier grouped these fields into the corn category. Corn was successfully separated from the soybeans, oats, hay, and natural vegetation. (fig. H).

The addition of TMS band 7 (2.08 - 2.35 μ) slightly decreased the correlation of the procedure defined fields with the ground truth fields. Patterns which may be related more to crop condition than to field boundaries become detectable with this combination. When the classifier was run on these fields, two categories contained the soybeans which had previously been in one category (fig. I). The differences in the soybeans fields between these categories may be related to the stage of development or to the variety planted. The "late corn" fields which were so well detected with band 5 were included in one of the soybeans categories when band 7 was used in classification

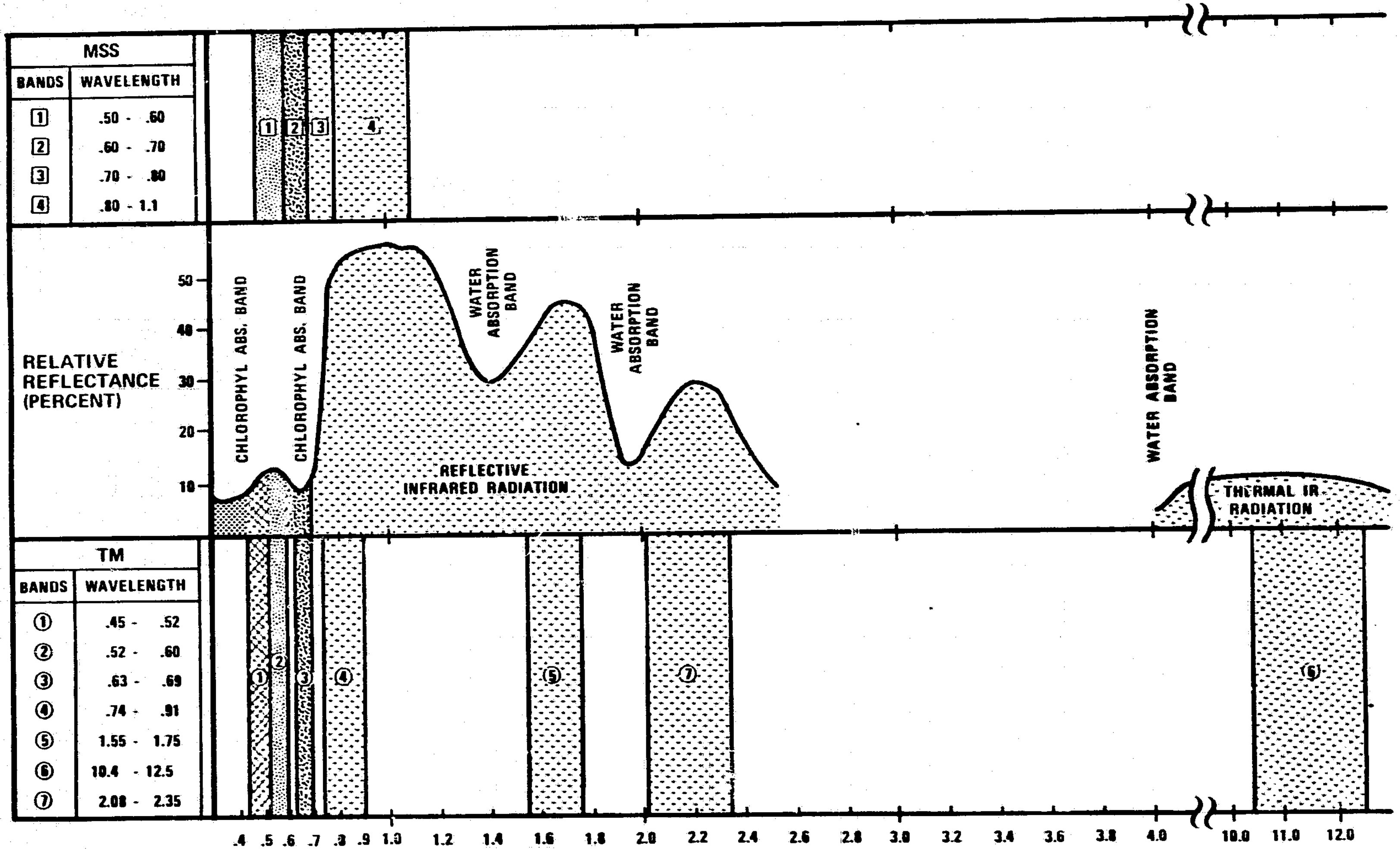
When the thermal band, TMS band (10.4 - 12.5 μ) was used with bands 2, 3, and 4 field definition was fair to good, but correlation with ground truth fields was further decreased. Many of the larger fields defined by other combinations were broken into smaller fields. After classification, patterns which had not been apparent in other combinations were visible (fig. J). The irregularities in the shapes which make up these patterns indicate that they may be related to features under the vegetative canopy or to differences in crop condition.

- Conclusion

SCS technology was efficiently and effectively applied to TMS data and will be considered a valuable tool in JSC's efforts to assess TM data. The SCS technology shows promise as a building block for an automated vegetation classifier which uses TM data.

Results of comparing TMS data to MSS data indicate that all field definition may be greatly increased by the TM resolution. Additional information in TM band 1 may allow more accurate crop type and crop condition assessment. Data from TM band 5 may improve field definition of different crop types. Data from TM band 7 may permit more effective discrimination of crop condition than has previously been possible. TM band 6 may allow crop condition assessment and sub-canopy feature identification and mapping.

SPECTRAL COVERAGE OF LANDSAT MULTISPECTRAL SCANNER AND THEMATIC MAPPER.



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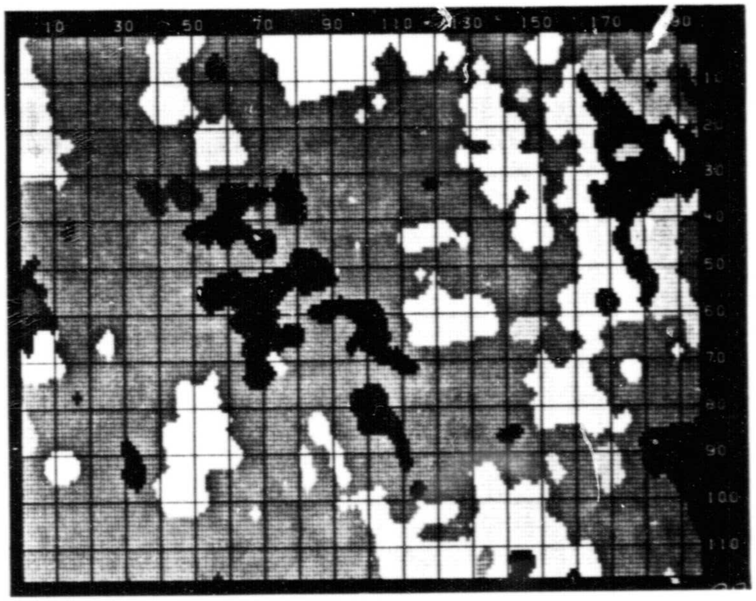
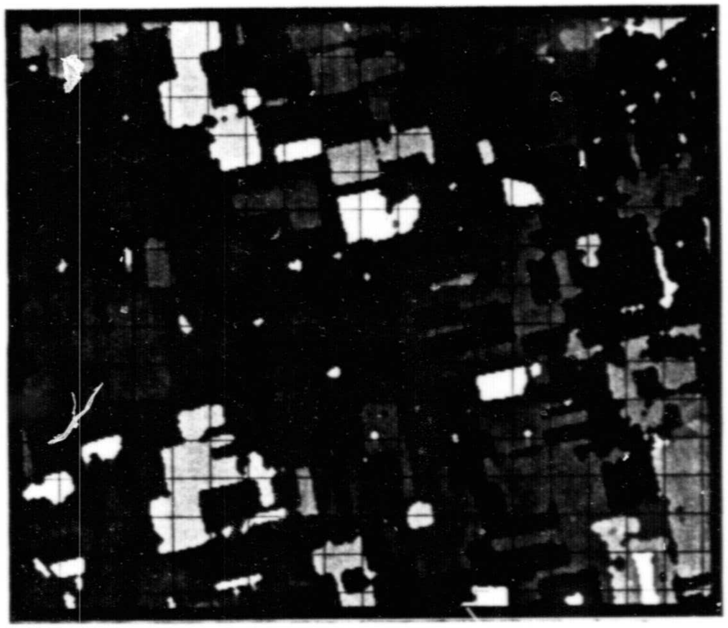


A. FIELDS DEFINED USING MSS BANDS 4, 5, AND 7. AUGUST 31, 1979; WEBSTER, IOWA.



B. FIELDS DEFINED USING TMS BANDS 2, 3, AND 4. AUGUST 30, 1979; WEBSTER, IOWA.

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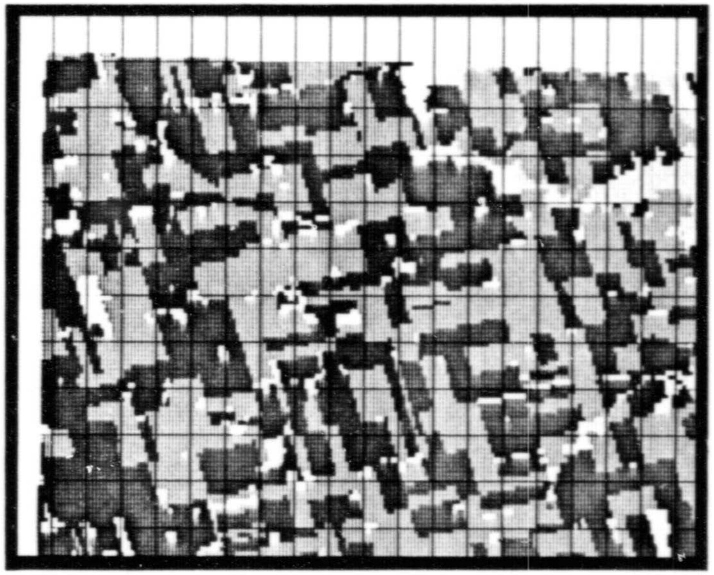

C. GROUND TRUTH OF WEBSTER COUNTY, IOWA, SEGMENT 893, 1979.

BLUE = SOYBEANS
BROWN = CORN
MAGENTA = OATS
GREEN = NATURAL VEGETATION
ORANGE = HAY

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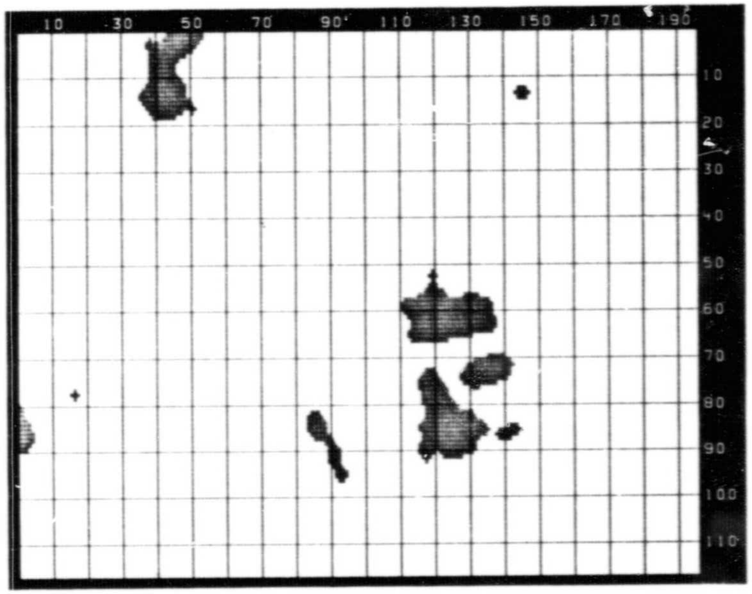
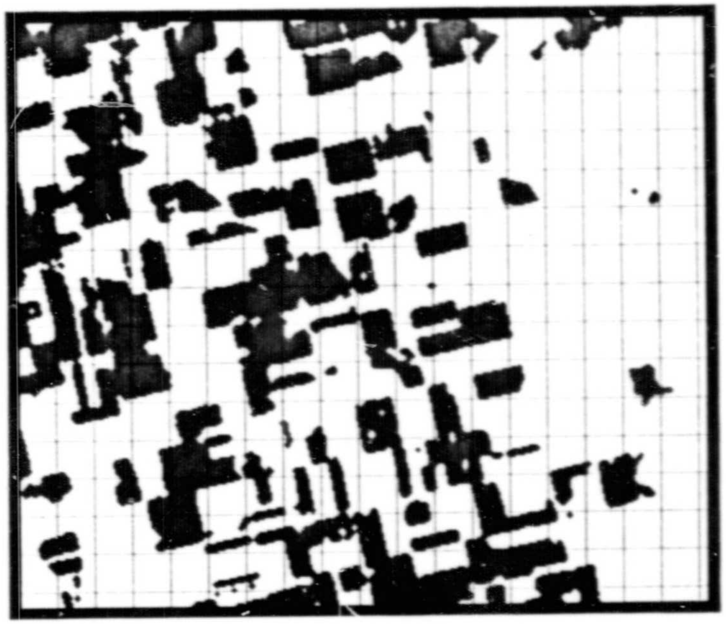
A TMS SCENE OF WEBSTER COUNTY,
IOWA, SEGMENT 893, AUGUST 30, 1979



D. THREE CATEGORY CLASSIFICATION BASED ON MSS BANDS 4, 5, AND 7. AUGUST 31, 1979; WEBSTER, IOWA.



E. THREE CATEGORY CLASSIFICATION BASED ON TMS BANDS 2, 3, AND 4. AUGUST 30, 1979; WEBSTER, IOWA.

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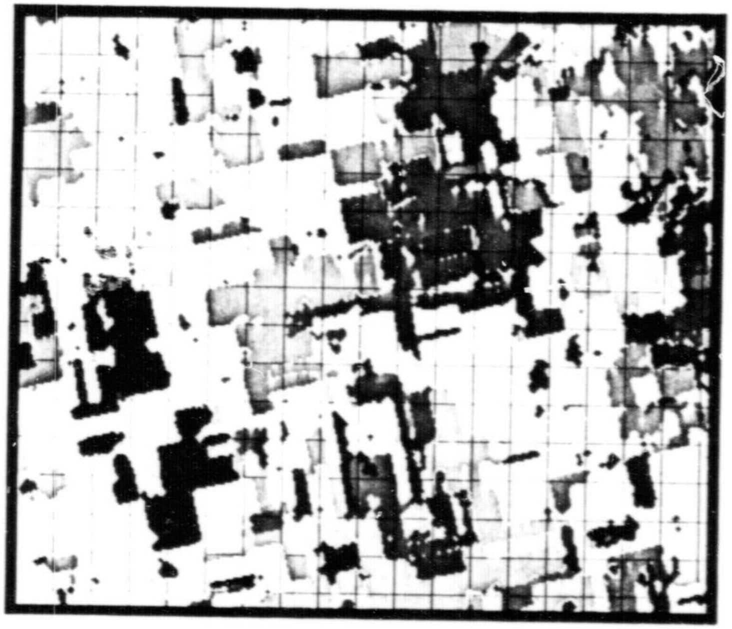
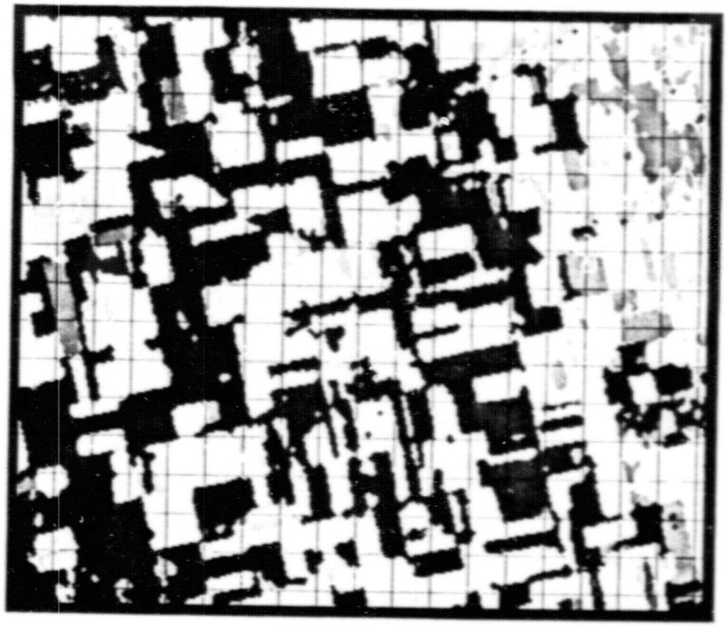


F. FIELDS DEFINED BY THE COMBINATION OF TMS BANDS 1, 2, 3, AND 2, 3, 4. AUGUST 30, 1979; WEBSTER, IOWA.



G. FIVE CATEGORY CLASSIFICATION BASED ON TMS BANDS 1, 2, 3, AND 2, 3, 4. AUGUST 30, 1979; WEBSTER, IOWA.

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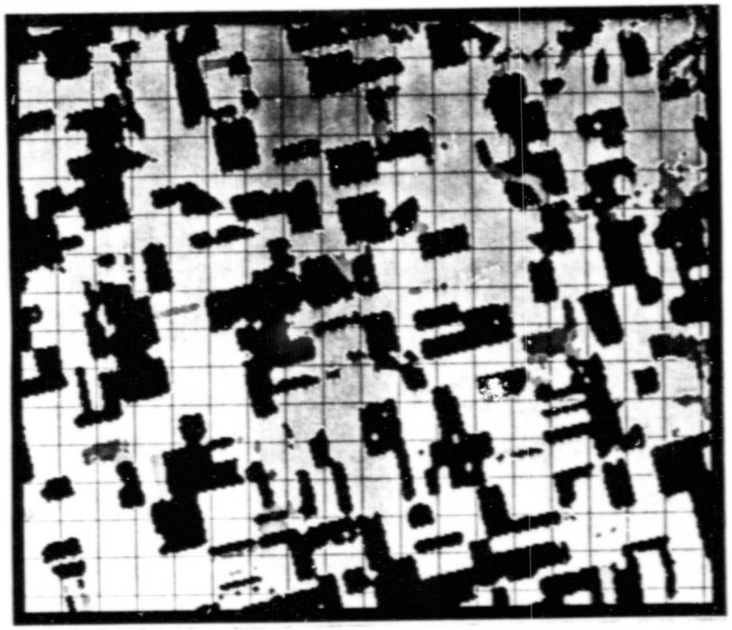
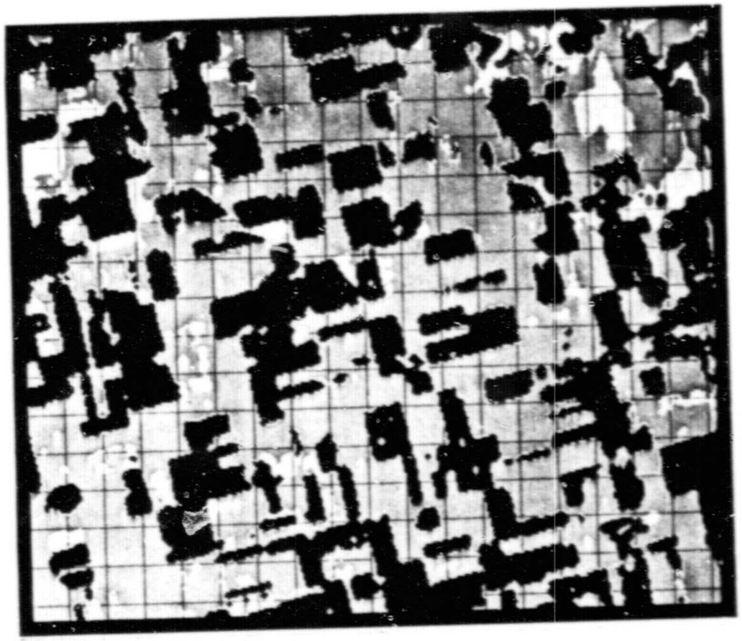


H. FIVE CATEGORY CLASSIFICATION BASED ON TMS BANDS 2, 3, 4 AND 2, 3, 5. AUGUST 30, 1979; WEBSTER, IOWA.



I. FIVE CATEGORY CLASSIFICATION BASED ON TMS BANDS 2, 3, 4 AND 2, 3, 7. AUGUST 30, 1979; WEBSTER, IOWA.

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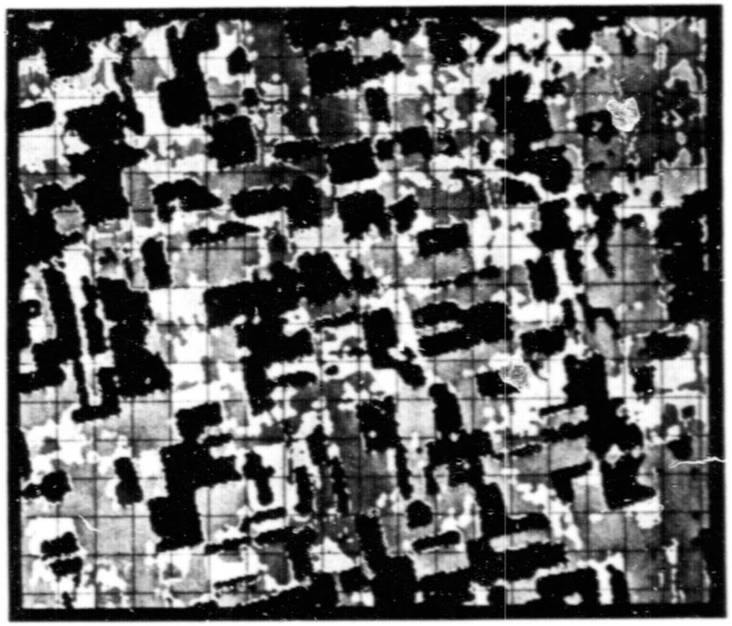


J. FIVE CATEGORY CLASSIFICATION BASED ON TMS BANDS 2, 3, 4 AND 2, 3, 6 (THERMAL). AUGUST 30, 1979; WEBSTER, IOWA.

3.3 HISTOGRAM ANALYSIS

- Objectives:
  1. To analyze each Thematic Mapper band to determine the structure and usefulness of the data.
  2. To support other working groups such as the feature selection and applications Quick Look by providing information on each of the TM bands.
- Approach:
  1. Characterize each band of TM data from histograms according to range, distribution, mean, standard deviation, and contribution to a color composite.
  2. Compare information found to that from TMS data.
  3. Study the histogrammed data in relationship to the segment black and white image to formulate a qualitative assessment of the usefulness of each band particularly in agricultural applications. Ground data will be plotted in histogram form as it becomes available to enhance this study.
  4. Replot all histograms to the same scale for a visual comparison and final presentation products.
- Data Requirements:
  - Histograms/all bands/all segments.
  - Black and white imagery/all bands/all segments.
  - Product 1 IR false color/1 per segment.
- Output Products:
  - Qualitative description of the TM data.
  - A set of histograms for each segment.

- Results:
  - Segment 9645 - Tecumseh, Michigan
    - Background - Scene Composition:
      - 8-10% Urban
      - 1% Water Bodies
      - 5% Trees, Natural Vegetation
      - 80% Agriculture
      - 2-4% Miscellaneous
    - Data Analysis:
      - Shapes of bands 1, 2, 3 are very similar
        - Narrow range
        - Unimodal
        - Sharp peak
        - Data skewed to the right
      - Main Difference - The counts where the bulk of the data occurs is very different for Band 1 and slightly different for Bands 2 and 3.
      - Band 4 - Distinctively different shape
        - Wide distribution of data values.
        - Biomodal or trimodal
        - Small cluster formed at low data values. (Probably water pixels.)
        - Data values higher than for other bands.
    - Conclusions:
      - Probably some separation between 3 distinct classes based on Band 4.
  - Segment 9646 - Toledo Ohio
    - Background - Scene Composition:
      - 1% Water
      - 4-5% Parks, Natural Vegetation
      - 94-95% Urban - Industrial, Commercial, Residential

- Data Analysis
  - All bands have a fairly smooth shape.
  - No sharp peaks.
  - Effective range of data is wider for Bands 1, 2, 3 than in Tecumseh scene.
  - Data is unimodal except for small cluster of data to the left in Band 4 (suspect this is the water pixels same as in segment 9645).
  - The values where the bulk of the data occurs is very similar for Bands 1, 2, 3 when compared to segment 9645.
  - Band 4 data values have shifted to the left considerably.
- Conclusions:
  - Homogenity of the scene evidenced in data structures observed.

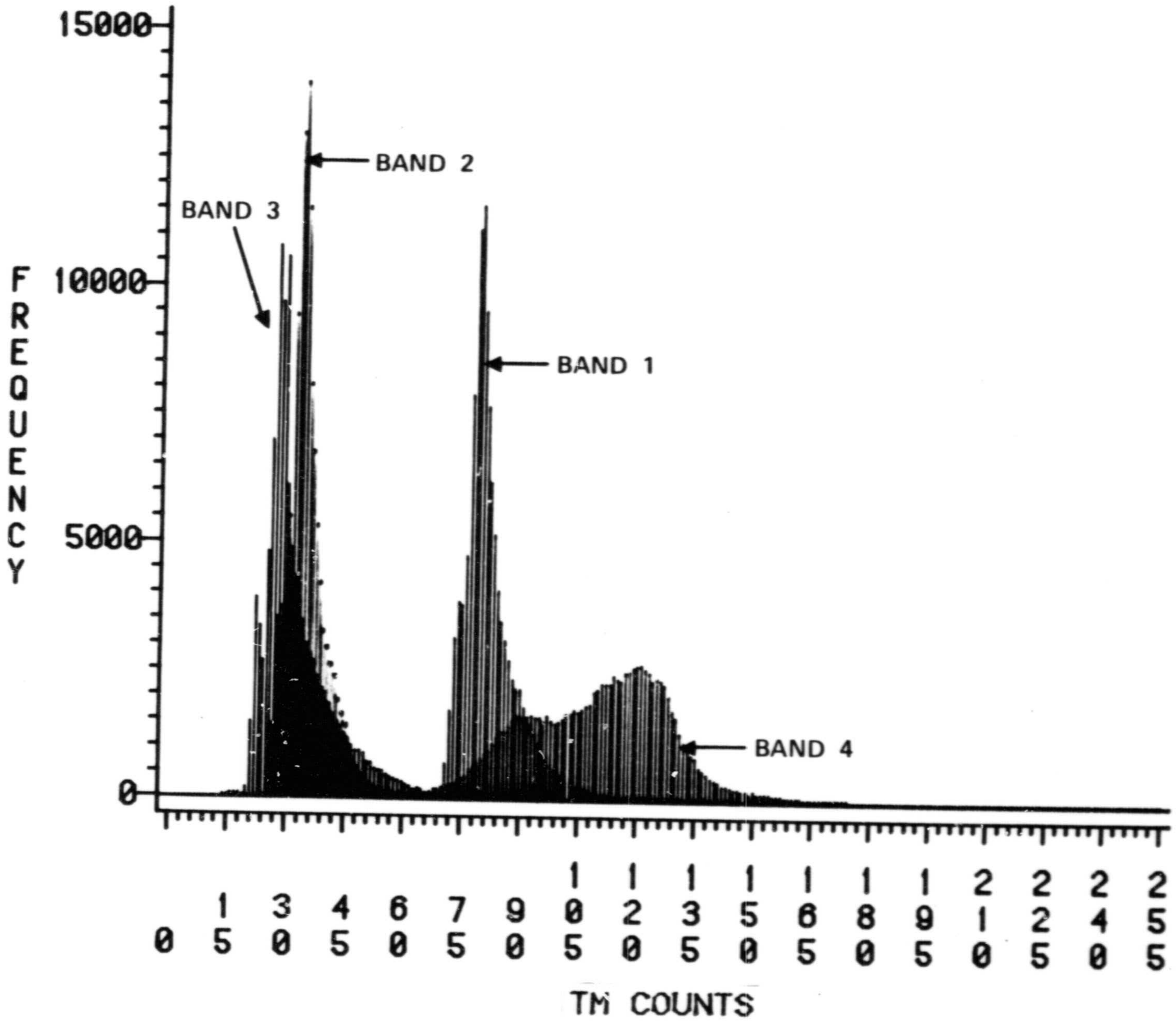
- Segment 9647 - Sandusky, Ohio
  - Background - Scene Composition
    - 78% Water
    - 1% Mining/Extraction
    - 2% Trees/Natural Vegetation
    - 15% Agriculture
    - 4% Miscellaneous
  - Data Analysis
    - Bands 1, 2, 3 very similar in shape
      - Narrow range for bulk of the data
      - Unimodal
      - Very sharp peaks
      - Data skewed to the right
    - Band 4
      - Biomodal
      - Wide distribution of data values
      - High spike at left

    - In comparison to segment 9645:
        - Band 1 distribution has shifted right.
        - Band 4 has only one distinct peak (distribution) in the middle data values where in segment 9645 two existed.
- Conclusions:
    - Strong evidence that water can be identified using Band 4 data.
    - Some evidence of water/land distinction in Band 1.
    - A correlation analysis of this scene would probably be misleading because of the structure of Band 4 with the sharp peak to the left.

- Segment 9652 - Water
    - Background - Scene Composition
        - 100% Water (two ships)
    - Data Analysis:
        - Data ranges are narrow for all bands.
          Band 1 has the widest variation.
          Band 2, 3 have approximately 50% of the data occurring at one data count.
        - The data values where water occurs in Band 4 are similar to those noted in previous scenes.
    - Conclusions:
        - Water appears to be in very narrow, defined distributions in each of the visible bands and the near IR.

SEGMENT 9645 - JULY 20, 1982

TM HISTOGRAM ANALYSIS



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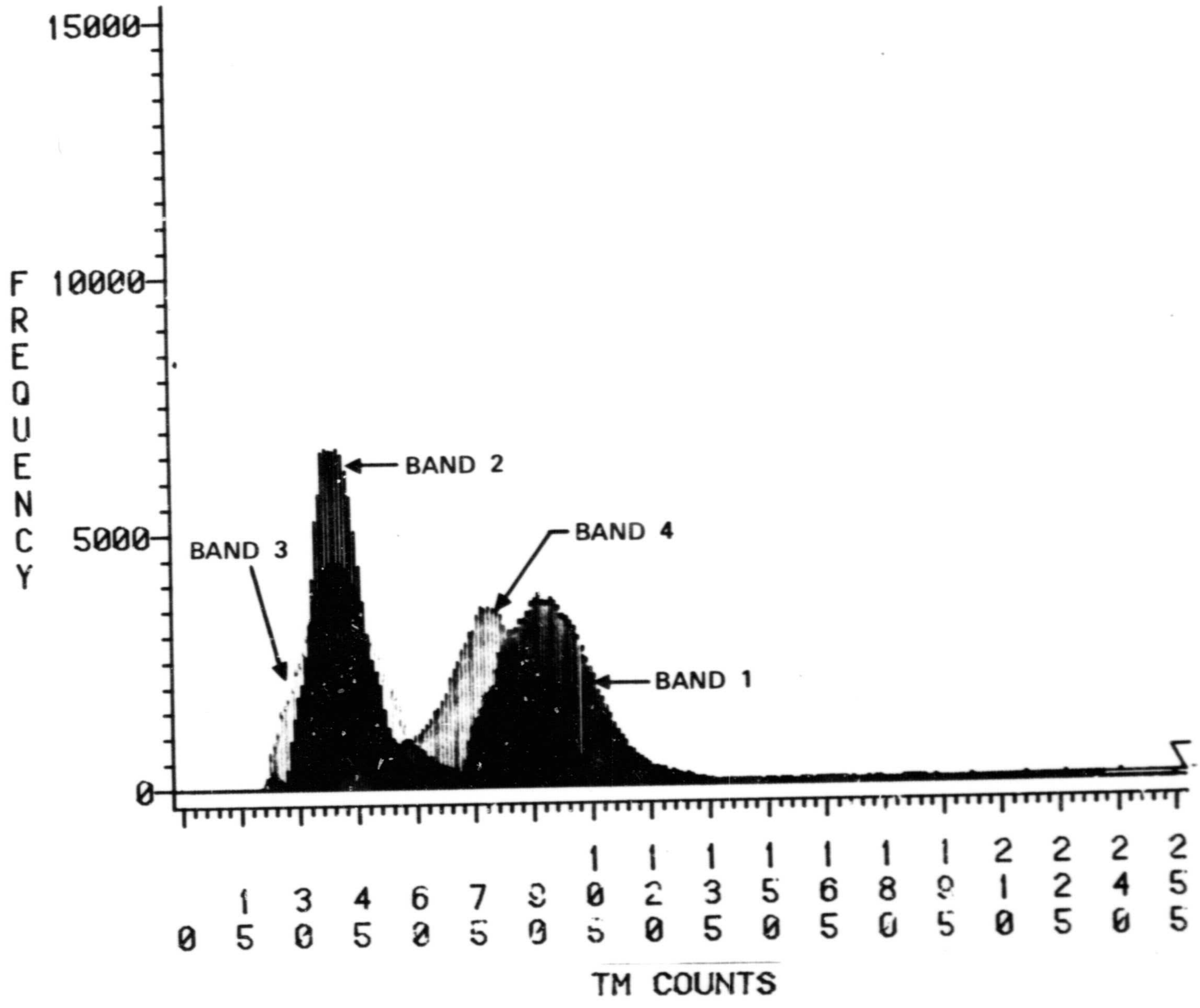
SEGMENT 9646 - JULY 20, 1982

TM HISTOGRAM ANALYSIS



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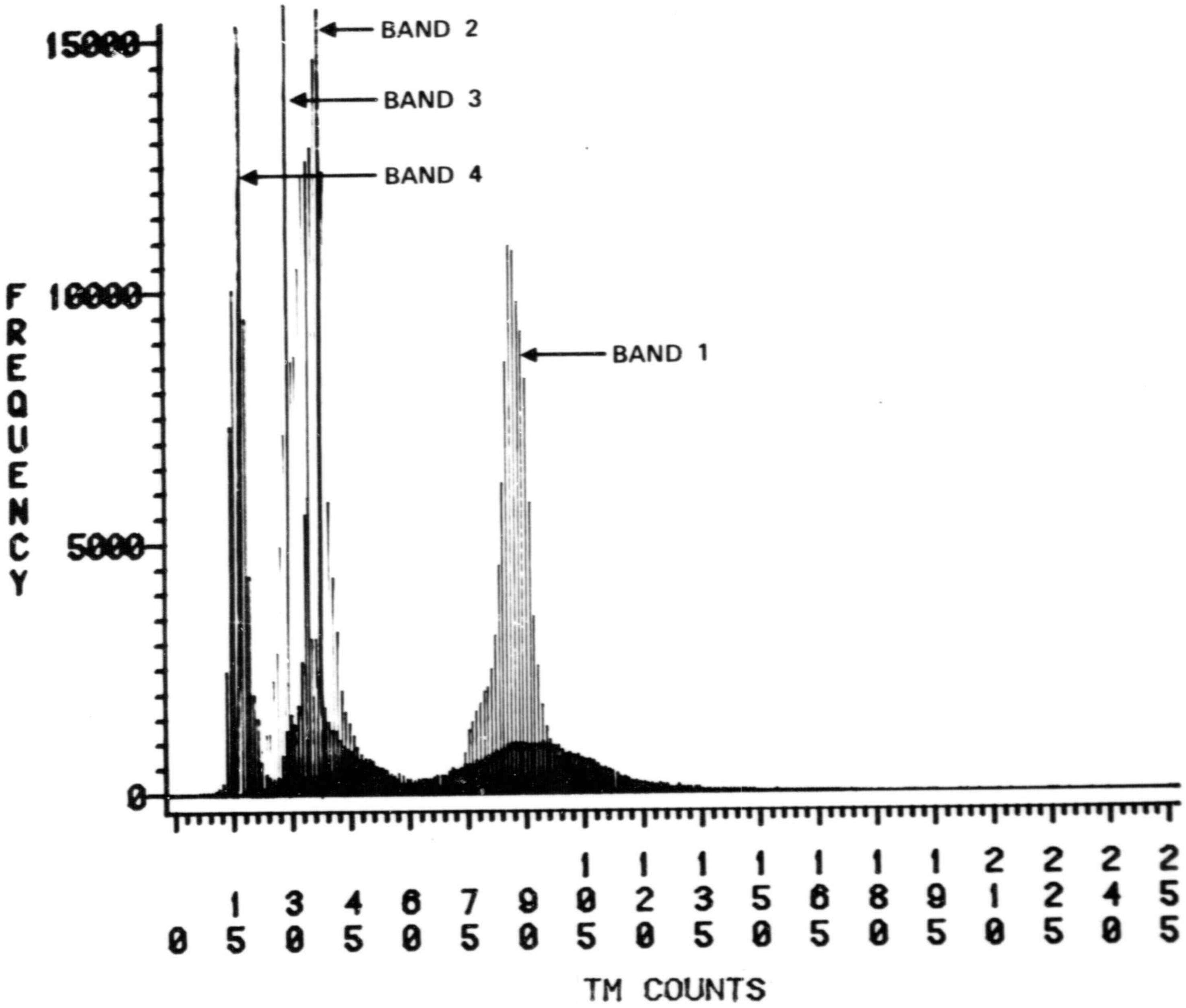
SEGMENT 9647 - JULY 20, 1982

TM HISTOGRAM ANALYSIS



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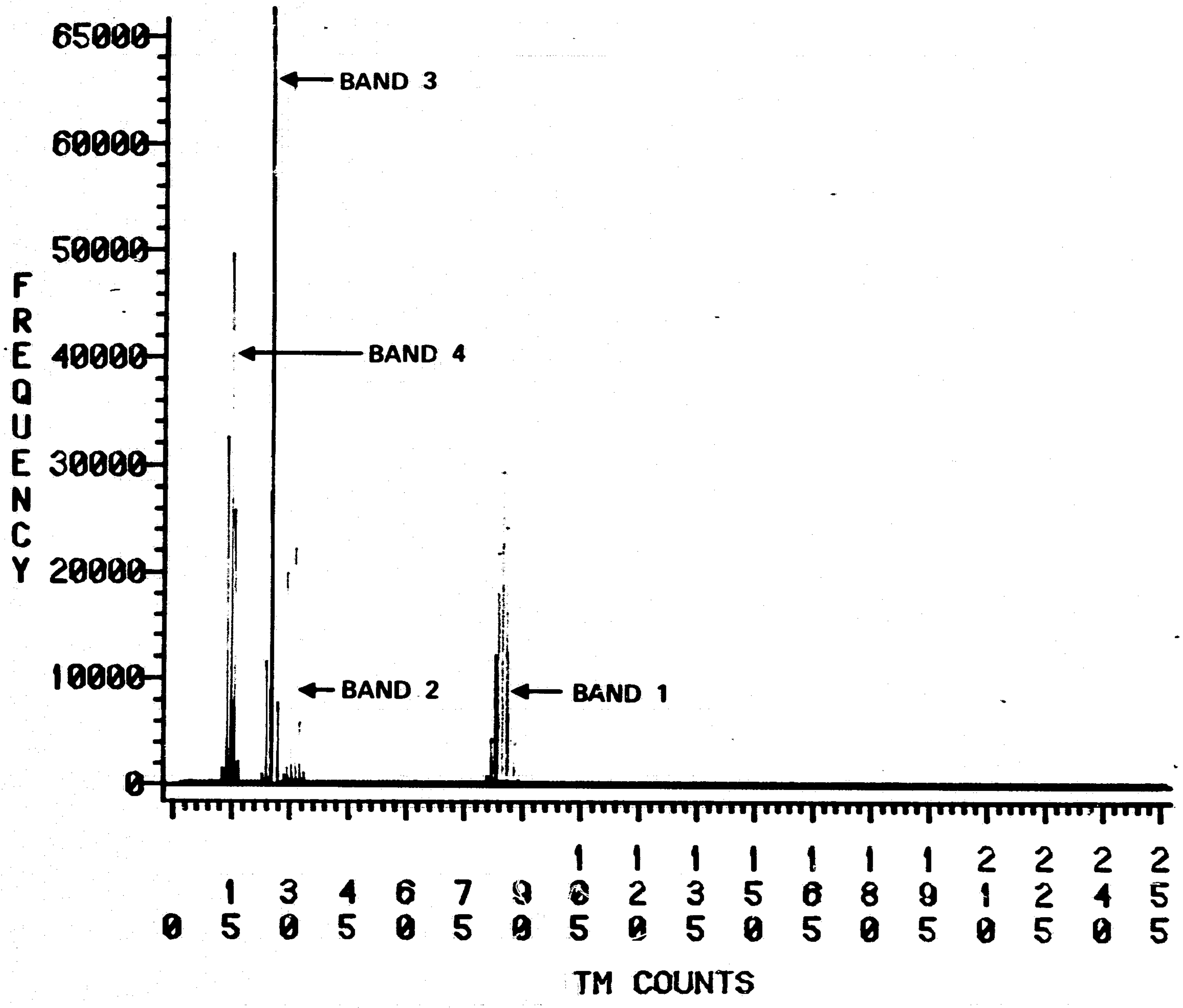
SEGMENT 9652 - JULY 20, 1982

TM HISTOGRAM ANALYSIS



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SEGMENT 9645 - TECUMSEH, MICHIGAN

BAND 1

BAND 2

BAND 3

BAND 4

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SEGMENT 9646 - TOLEDO, OHIO

BAND 1

BAND 2

BAND 3

BAND 4

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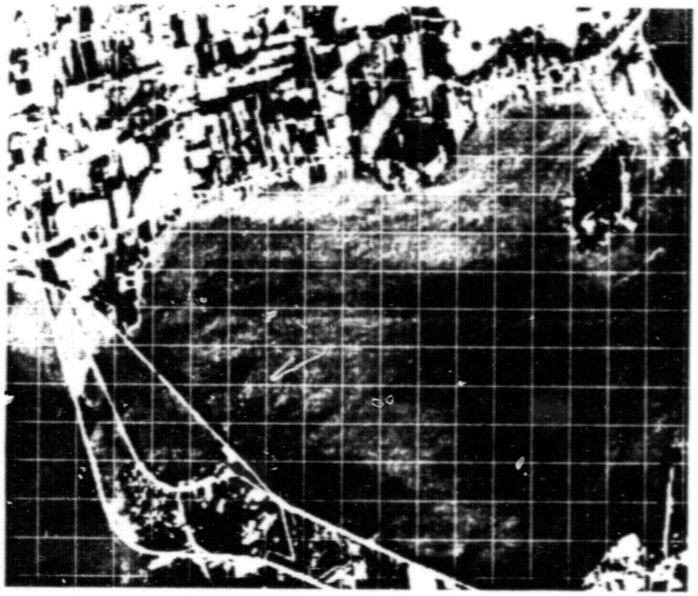
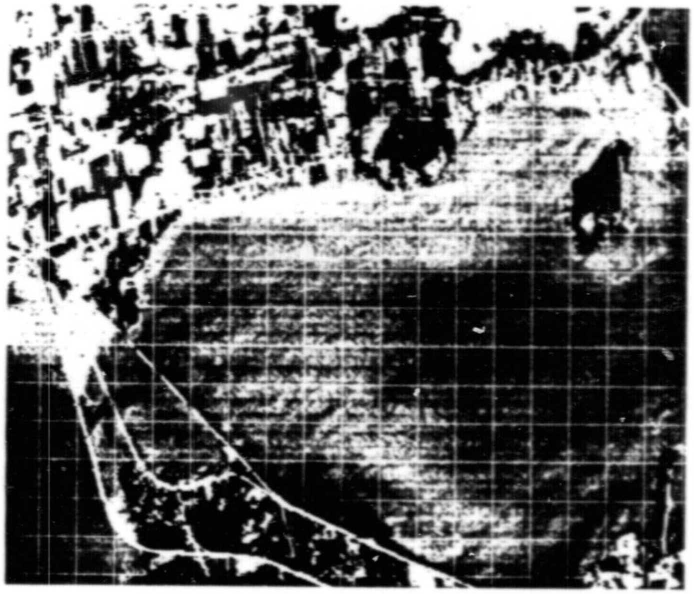
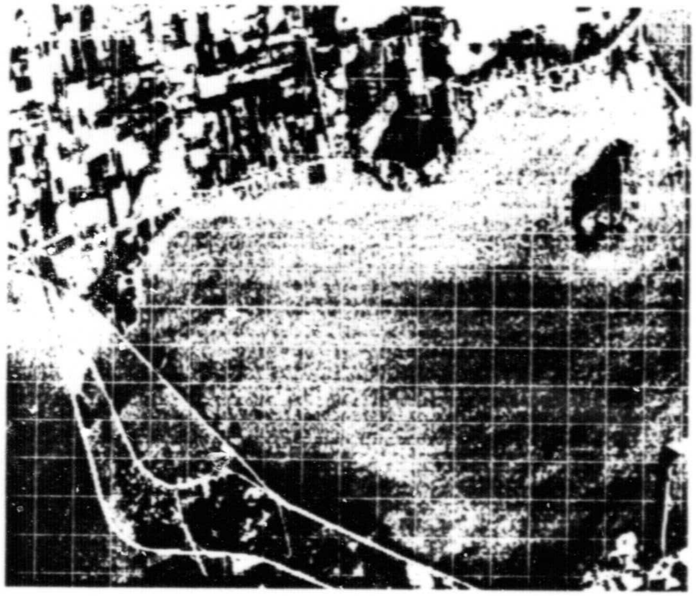
SEGMENT 9647 - SANDUSKY, OHIO



BAND 1



BAND 2



BAND 3

BAND 4

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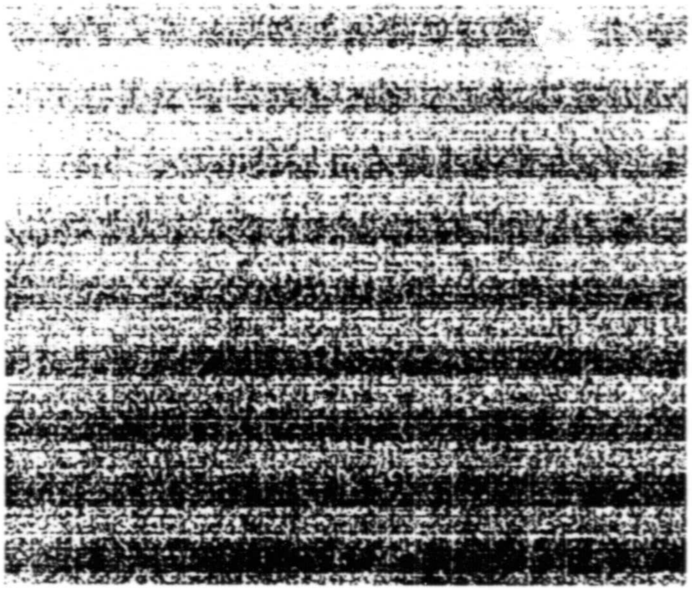
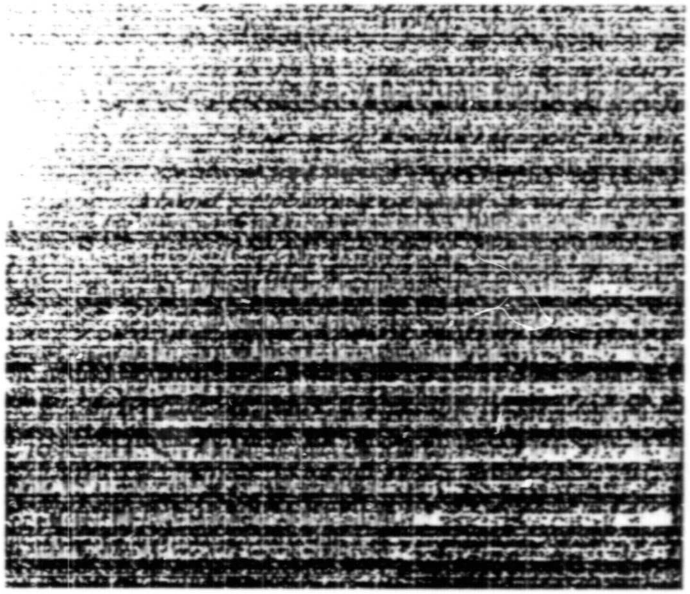
SEGMENT 9652 - WATER

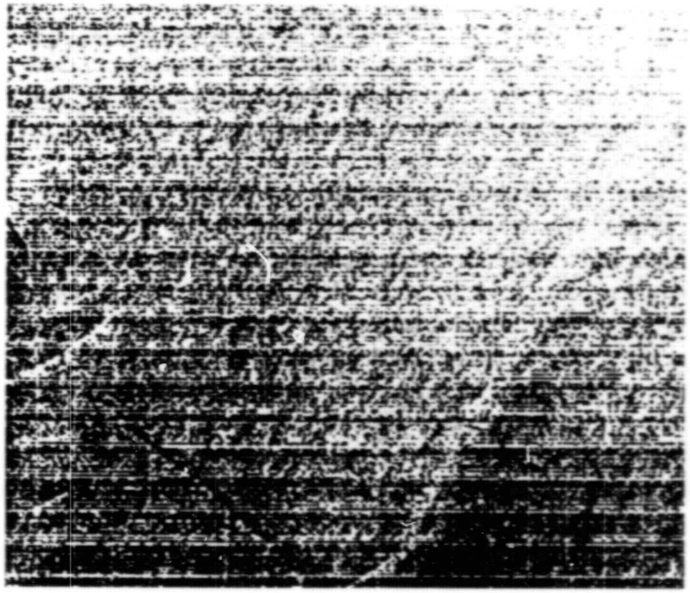


BAND 1



BAND 2

BAND 3



BAND 4

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3.4 PRINCIPAL COMPONENTS STUDY

- Objective:

  Identify dimensionality of Thematic Mapper feature space.

- Approach:

  Perform principal components analysis on agricultural segments.

- Output Products
  - Transformation matrix
  - Color and gray scale maps for several segments.
  - Bivariate plots for significant dimensions.

- Principal Components Analysis Results
  - Data
    - Detroit scene Thematic Mapper data
    - Five agricultural segments

      0231 Fulton, Ohio
      9645 Tecumseh, Michigan
      9468 Ann Arbor, Michigan
      9649 West Toledo, Ohio
      9651 Ontario, Canada
    - Segments analyzed separately and as combined data set
    - Results similar
    - Only combined analysis will be presented
  - Visible bands highly correlated
  - First two principal components explain 96% of the variance
  - Have tasselled cap in first two components.
  - Principal component 1
    - Contrast between visible and near IR
    - Stable

- Same coefficients for Simulated Thematic Mapper as for TM Detroit scene.
- Same coefficients if calculated on all agricultural segments or individual segments.

- Principal component 2
    - Near IR plus a weighted sum of the visible bands.
    - Coefficients of visible bands vary a bit.
- Principal component 3
    - Does seem to aid in cluster detection.
    - Band 1 to Band 3 contrast or Band 1 to Band 2 contrast depending on the scene.
- Even though principal components indicate the data is two dimensional, third component helps in cluster detection. It also appears to give information in color images.
- Results on the Simulated Thematic Mapper data support the above analysis.
    - Webster County, August 6, 1980
    - Correlation struction preserved
    - First two components
        - Have similar coefficients
        - Again explain 96% of the variance.

THEMATIC MAPPER DATA
JULY 20, 1982 DETROIT SCENES
PRINCIPAL COMPONENTS ANALYSIS

CORRELATION MATRIX

	BAND 1	BAND 2	BAND 3
BAND 1			
BAND 2	0.9255		
BAND 3	0.8976	0.9248	
BAND 4	-0.4583	-0.3702	-0.3310

TRANSFORMATION MATRIX
FOR PRINCIPAL COMPONENTS

	(1)	(2)	(3)
BAND 1	0.55469	0.07893	0.-6590
BAND 2	0.55043	0.20409	0.11057
BAND 3	0.54115	0.25256	-0.72869
BAND 4	-0.31065	0.94251	0.11555

VARIANCE EXPLAINED

Component	1	2	3	4
Eigenvalues	3.0508	0.7928	0.0919	0.0646
Variance	.763	.198	.023	.016

- First two principal components explain 96% of the variance.
- Visible bands are highly correlated.

SIMULATED THEMATIC MAPPER DATA
AUGUST 6, 1980 WEBSTER COUNTY
PRINCIPAL COMPONENTS ANALYSIS

CORRELATION MATRIX

BAND 1			
BAND 2	0.9466		
BAND 3	0.8773	0.8724	
BAND 4	-0.3606	-0.3407	-0.5197
	BAND 1	BAND 2	BAND 3

TRANSPORTATION MATRIX FOR PRINCIPAL COMPONENTS

	(1)	(2)	(3)
BAND 1	0.54535	0.26049	-0.36009
BAND 2	0.54226	0.28548	-0.36031
BAND 3	0.54936	0.00815	0.83555
BAND 4	-0.32674	0.92227	0.20586

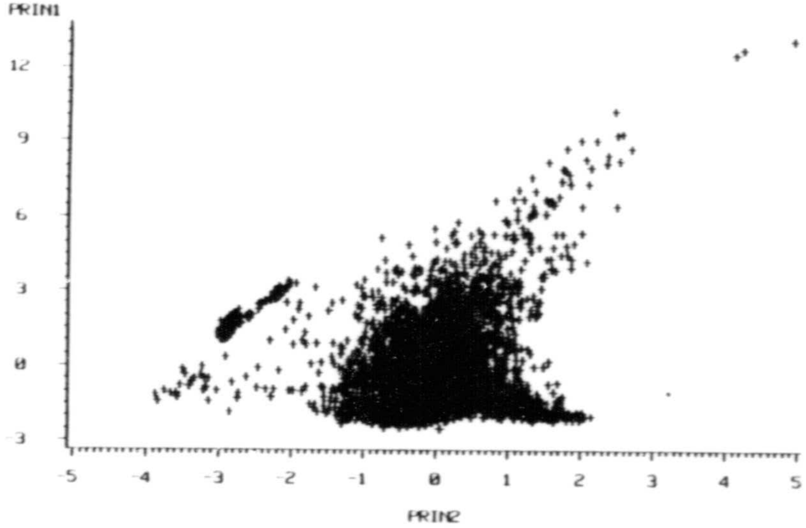
EXPLAINED VARIANCE

Component	1	2	3	4
Eigenvalues	3.0411	0.7881	0.1177	0.0531
Variance	.760	.197	.0294	.013

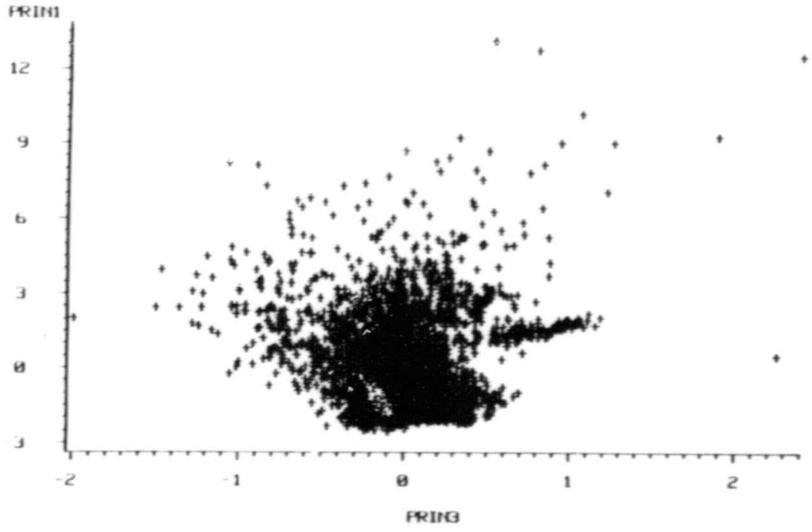
- Confidence in quick look study.
  - Correlations similar
  - First two components have similar coefficients
- Confidence in studies using simulated data.

e-2

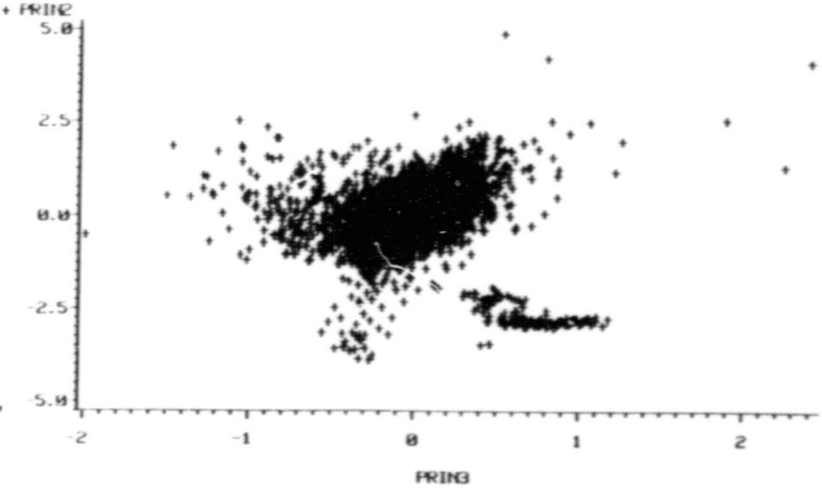
Detroit scene--thematic mapper--July 20,1982



- NOTE TASSEL CAP
- NOTE TWO CLUSTERS



- SECOND CLUSTER SHOWS SEPARATION ALONG THIRD PRINCIPAL COMPONENT



- SECOND CLUSTER SHOWS SEPARATION ALONG THIRD COMPONENT

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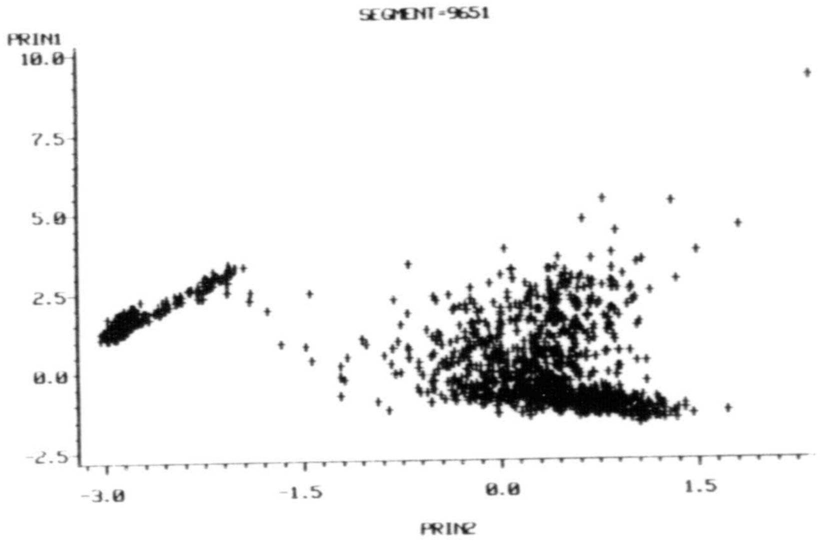
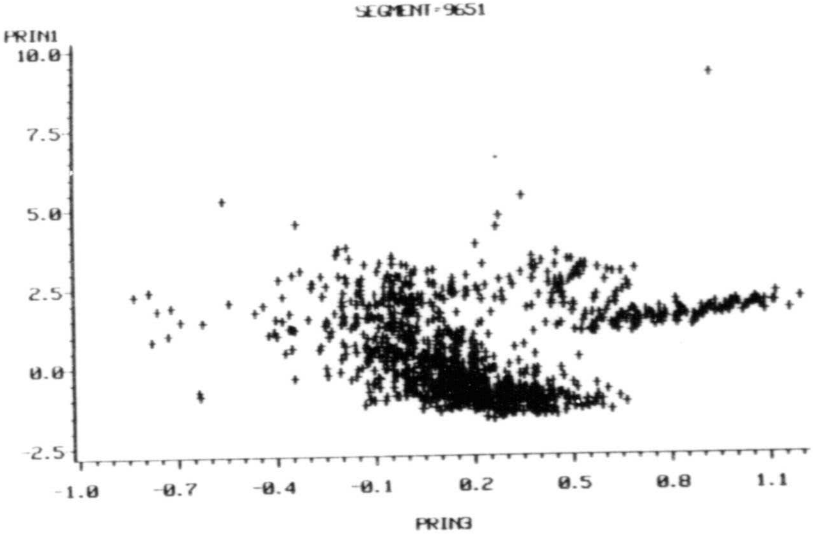
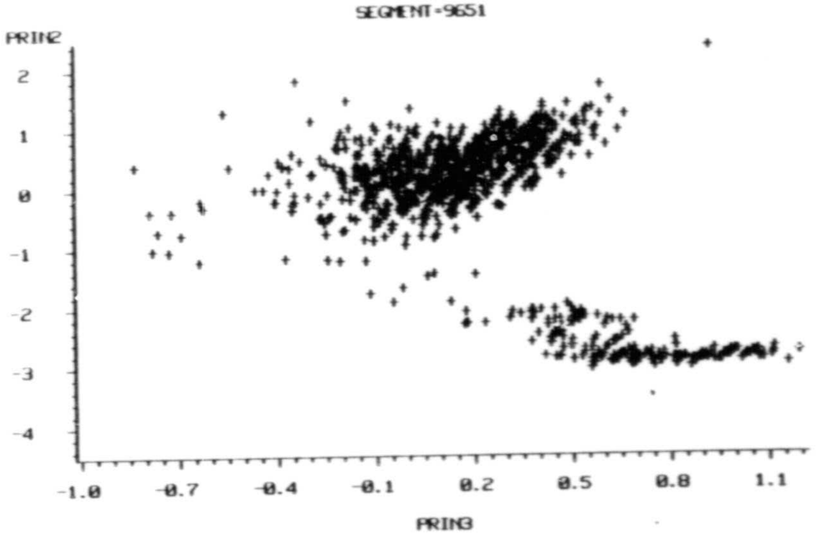
Detroit scene--thematic mapper--July 20,1982



- TWO DISTINCT CLUSTERS EVIDENT – PERHAPS WATER



- POSSIBLY THREE CLUSTERS



- POSSIBLY THREE CLUSTERS
- NOTE PRINCIPAL COMPONENT THREE AIDS IN THE SEPARATION

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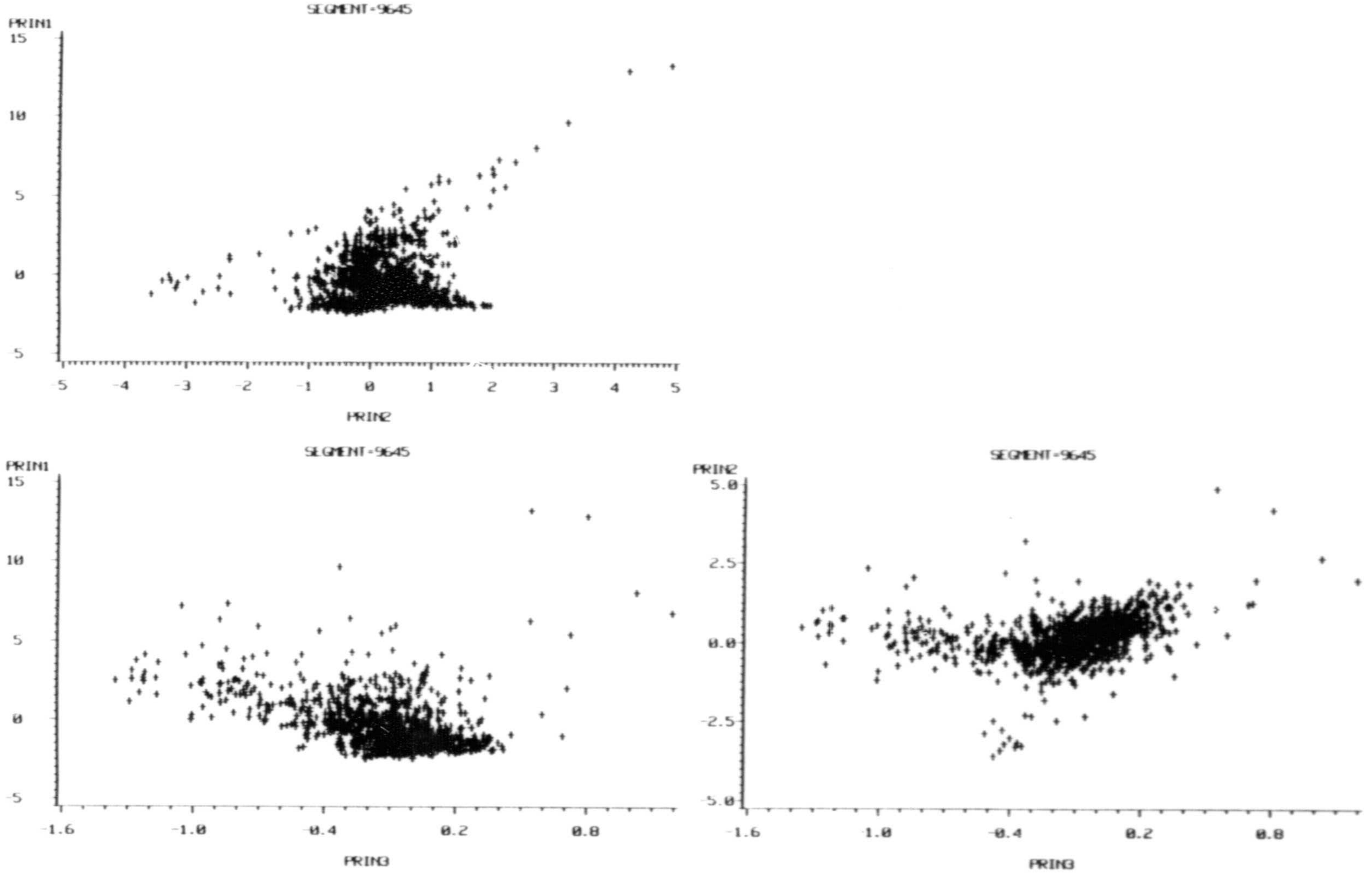
Detroit scene--thematic mapper--July 20,1982



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Principal Components Analysis

- Image Analysis
  - Agricultural fields
    - Cut fields
    - Vegetative stages
    - Bare soil
  - Natural vegetation
    - Trees
  - Man made structures
    - Urban areas
    - Homesteads
  - Terrain
    - Drainage patterns

Principal Components Analysis

Location

Fulton, Ohio - Urban and Agriculture
Segment 0231

Gun Assignments

Green = First principal component
Red = Second principal component
Blue = Third principal component

Transformation

Calculated over all pixels of the segment

Component	Band			
	1	2	3	4
First	.5348	.5403	.5467	-.3510
Second	.2532	.2339	.1192	.9311
Third	-.7909	.2915	.5329	.0736

Interpretation

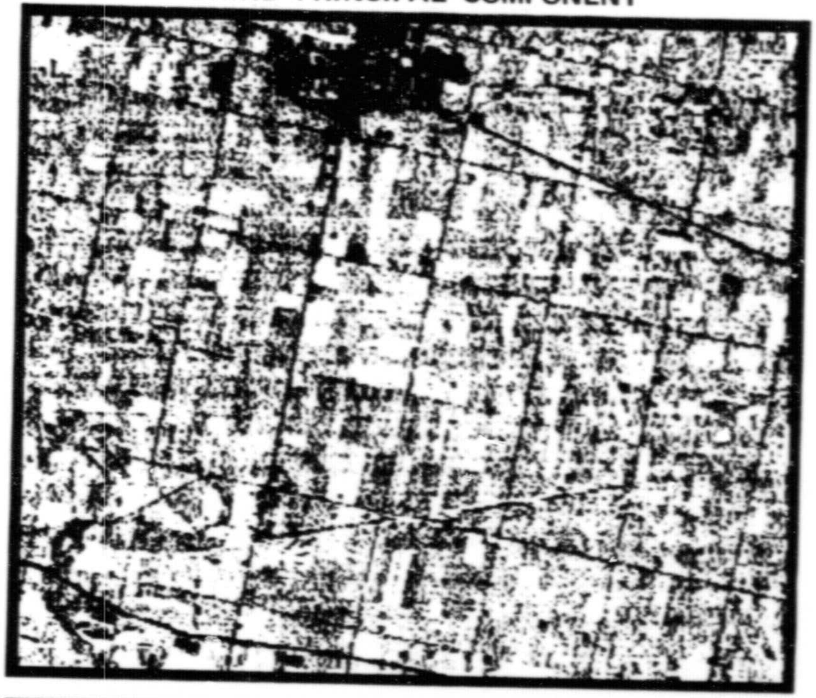
First = Contrast of visible and near IR
Second = Near IR plus small visible contribution
Third = Contrast Band 1 versus Band 2 and 3

PRINCIPAL COMPONENTS ANALYSIS – FULTON, OHIO

FIRST PRINCIPAL COMPONENT

SECOND PRINCIPAL COMPONENT

THIRD PRINCIPAL COMPONENT



FOURTH PRINCIPAL COMPONENT

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Principal Components Analysis

Fulton, Ohio

Image Color	Object is highly Reflective in	Examples
Green	Visible Bands	Industrial, roads, water
Yellow	All Four Bands	Homesteads, parking lots, roads
Red	Near IR Band	Vegetated agricultural fields
Purple	Near IR and Bands 2 and 3	Trees
Blue	Bands 2 and 3, but not Band 1	Ripe fields
White	Near IR, Band 3, Band 2, but not Band 1	Cut agricultural fields

FULTON, OHIO - SEGMENT 231

THREE DISTINCT CATEGORIES OF AGRICULTURAL FIELDS (RED AND PURPLE)
  RIPE WHEAT (BLUE)
  HOMESTEADS (YELLOW)
  TREES (PURPLE)
  BARE SOIL (WHITE)
  URBAN (GREEN)
  ROADS (GREEN)
  DRAINAGE PATTERN MOTTLED IN UPPER RIGHT)

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Principal Components Analysis

Location

Tecumseh, Michigan - Agricultural
Segment 9645

Gun Assignments

Green = First principal component
Red = Second principal component
Blue = Third principal component

Transformation

Calculated over all pixels of the segment

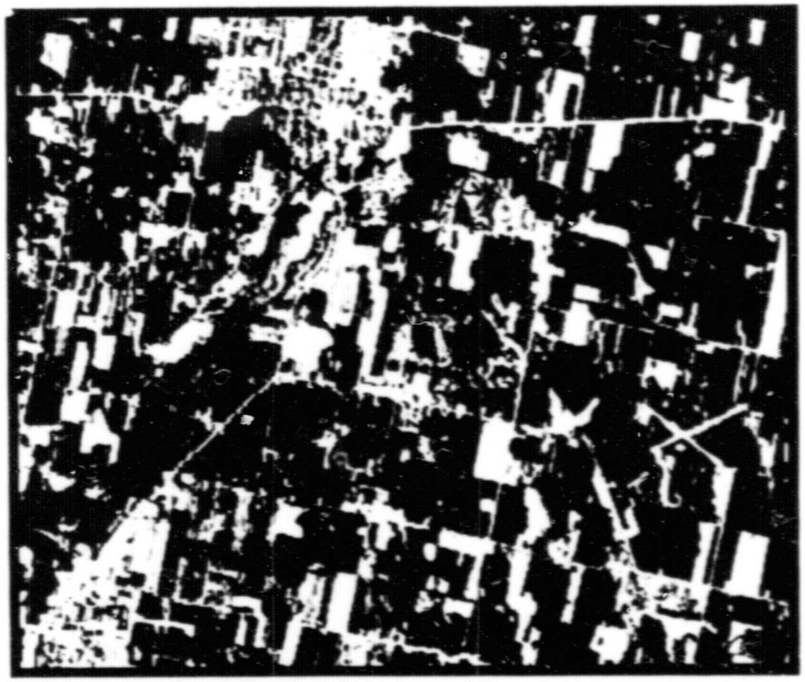
Component	Band			
	1	2	3	4
First	0.5464	0.5449	0.5553	-0.3099
Second	0.1953	0.2455	0.0943	0.9448
Third	-0,8055	0.3199	0.4976	0.0337

Interpretation

First = Contrast of visible and near IR
Second = Near IR plus small visible contribution
Third = Contrast of Band 1 versus Bands 2 and 3

PRINCIPAL COMPONENTS ANALYSIS – TECUMSEH, MICH.

FIRST PRINCIPAL COMPONENT



THIRD PRINCIPAL COMPONENT

SECOND PRINCIPAL COMPONENT

FOURTH PRINCIPAL COMPONENT

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PRINCIPAL COMPONENTS ANALYSIS

TECUMSEH, MICHIGAN — SEGMENT 9645

Principal Components Analysis

Location

Ann Arbor, Michigan - Urban and Agriculture

Segment 9648

Gun Assignments

Green = First principal component

Red = Second principal component

Blue = Third principal component

Transformation

Calculated over all pixels of the segment

Component	Band			
	1	2	3	4
First	0.5618	0.5516	0.5628	-0.2516
Second	0.0989	0.2113	0.1255	0.9643
Third	-0.6102	0.7672	0.1793	0.0821

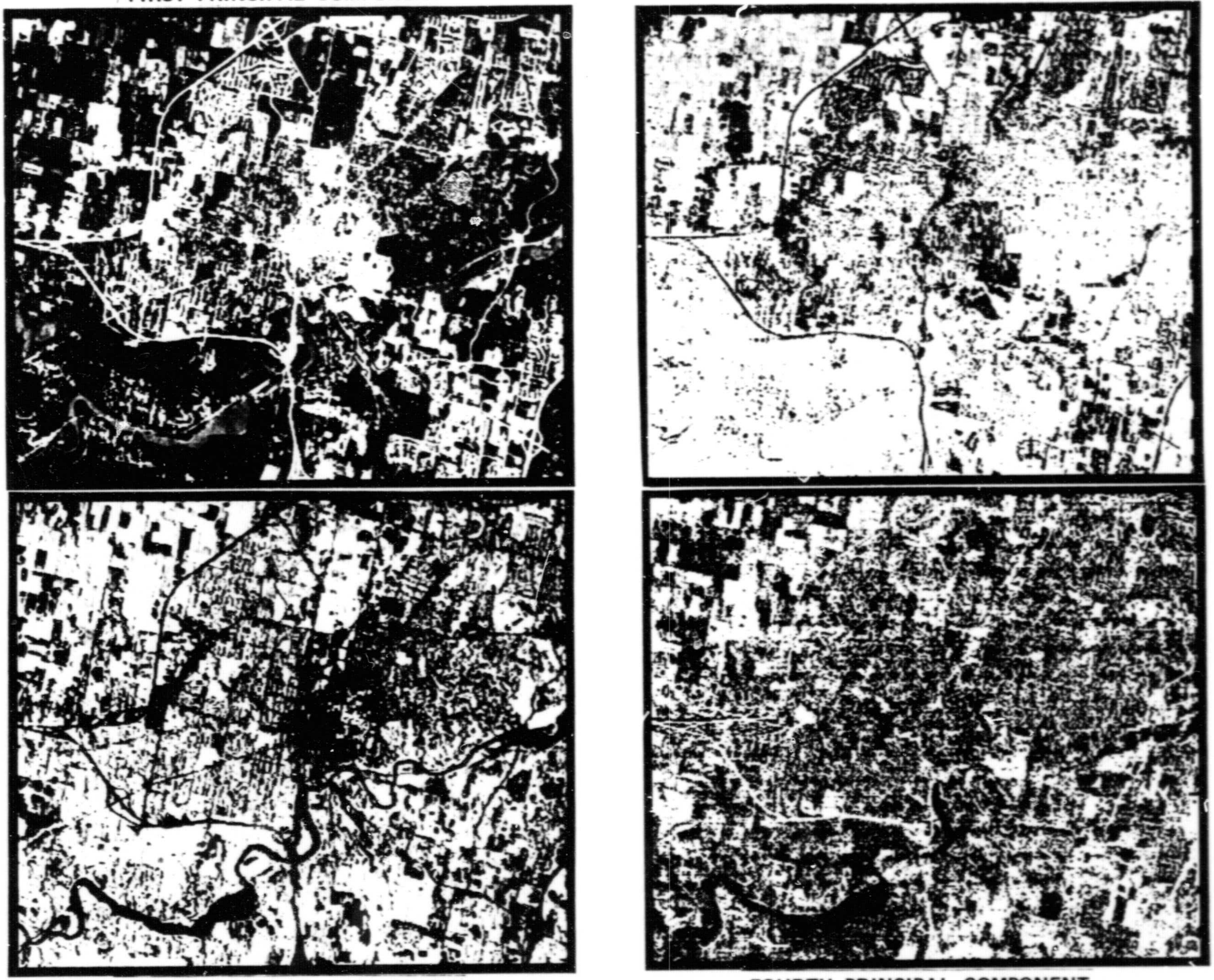
Interpretation

First = Contrast of visible and near IR

Second = Near IR plus small visible contribution

Third = Contrast Band 1 versus Band 2

PRINCIPAL COMPONENT ANALYSIS—ANN ARBOR, MICH.



FIRST PRINCIPAL COMPONENT

THIRD PRINCIPAL COMPONENT

SECOND PRINCIPAL COMPONENT

FOURTH PRINCIPAL COMPONENT

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PRINCIPAL COMPONENTS ANALYSIS

ANN ARBOR, MICHIGAN - SEGMENT 9648

HIGH DENSITY URBAN/INDUSTRIAL (GREEN OR DARK YELLOW)

OLD RESIDENTIAL (MOTTLED PURPLE)

NEW RESIDENTIAL (BRIGHT YELLOW)

OTHER DISTINCTIVE, UNIDENTIFIED FEATURES

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3.5 MAXIMUM LIKELIHOOD/ISOCLASS

- Rationale:

  Numerous technologies have been developed for Landsat MSS data to perform crop inventory research and development. An understanding of the applicability and completeness of these technologies for the TM data is necessary for future planning and implementation.

- Assess the adaptability of maximum likelihood classifier and ISOCLASS clustering routine for use with TM data.

- Approach:

  Process TM sample segments with EOD-LARSY software to determine overall usefulness and quality of Thematic Mapper data.

- Software Readiness:

  The following processors have been successfully executed and are considered functional with TM data:

  - Histogram
  - Gray Map
  - Dot Data
  - ISOCLASS
  - Label
  - N-Dimensional Histogram
  - Scatter Plot
  - Classify
  - Display

- Output Product:

  - Conditional Cluster Map
  - Unconditional Cluster Map
  - Gray-Shade Class Map

- Results:

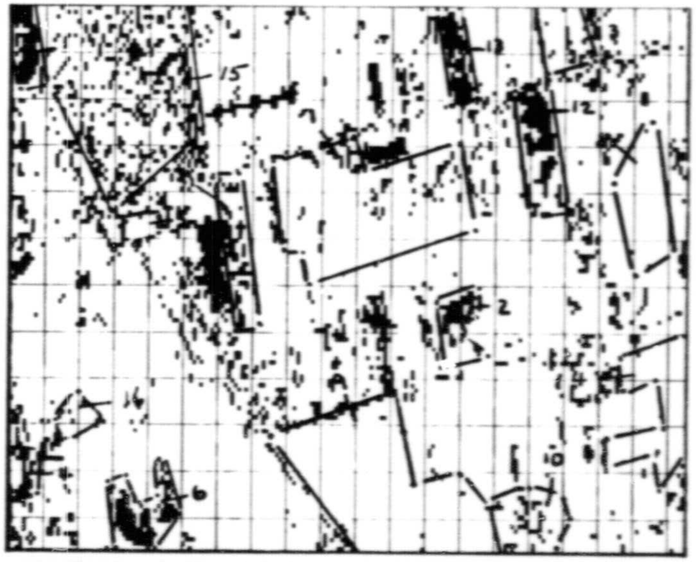
  - Due to limitations established for LACIE size segments, classification and clustering of a full size 308 x 366 TM sample segment could not be achieved. However, it is possible to process a smaller portion of a TM scene which corresponds to 117 lines by 196 pixels.

TM 9645 TECUMSEH, MICHIGAN

AREA PROCESSED
FROM TM SEGMENT

TM ENLARGEMENT 117 X 196

ISOCLS CLUSTER MAP, 4 BANDS



THREE-CATEGORY MAXIMUM
LIKELIHOOD CLASSIFICATION

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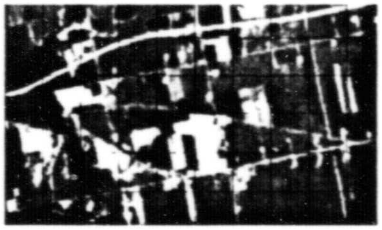
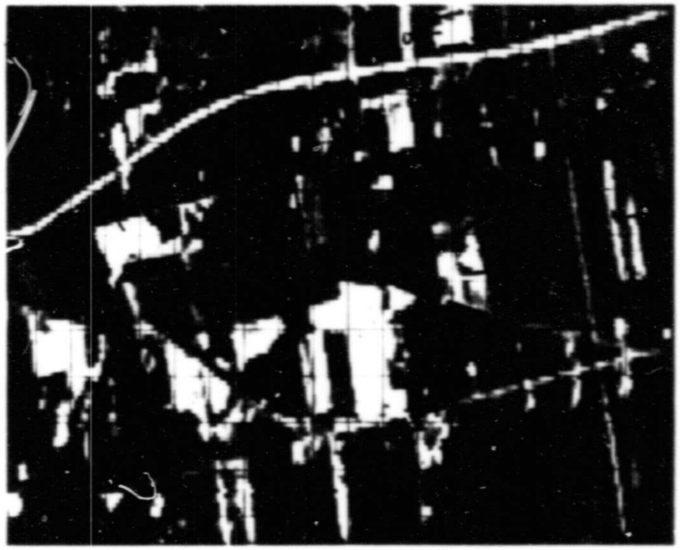
TM-0231 — FULTON, OHIO



AREA PROCESSED FROM TM SEGMENT



TM ENLARGEMENT
117 X 196

ISOCLS CLUSTER MAP

THREE-CATEGORY
MAXIMUM LIKELIHOOD
CLASSIFICATION

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- Sample segments selected for processing were 9645 Tecumseh, Michigan, and 0231 Fulton, Ohio. Each scene represented areas of diversified agriculture, with suitable nonagricultural land use representation.
- Using minimum 30 type one dots and 60 type two dots, a three category classification was produced.

Segment	Category	Classified	Bias Corrected
9641	Small Grains	24.3	19.2
	Summer Crop	52.8	46.6
	Other	22.3	19.2
0231	Small Grains	16.3	19.2
	Summer Crop	63.9	59.6
	Other	19.7	21.1

- Evaluation of cluster: Maps and Ground Verification

9645	Fields No.	Ground Truth
	1, 2, 3	Corn crops
	4, 5	Idle crop, bare soil
	6	Soybeans
	7	Varying stages of corn development
	8, 9	Corn
	10	Soybeans
	11	Weeds
	12	Clover
	13	Other Hays
	14	Trees
	15	Urban
	16	Small Grains

0231	Field No.	AI Interpretation
	1, 2, 3, 4, 8	Summer crop (corn and soybeans)
	5, 6, 7	Small grains
	9, 10	Water
	11	Trees
	12	Urban

- Conclusion:
  - Classifications for 9645 is considered acceptable. 0231 is marginal.
  - Clusters from a single acquisition using TM data appear to be uniform and homogeneous when compared to the imagery.
  - Variation in crop mixture is illustrated in greater detail with TM data than old MSS.
  - Areas normally 'designated other' classified with easy into "other" category. Very little confusion with crop types.
- Recommendation:
  - For future Quick Look or data processing with TM data, each processor should be modified to accept new scene size and dimensions.
  - Investigate the possibility of extracting LACIE size segment areas for classification purposes.

EOD-LARSYS
PROCESSORS

PROCESSORS	FUNCTION
HIST	One-dimensional histograms
GRAYMAP	Gray-scale maps
STAT	Statistics
ISOCLS	Iterative Self-Organizing Clustering System
SELECT	Channel selection
CLASSIFY	Data Classification
DISPLAY	Displaying classification results
DATATR	Data transformation
TRSTAT	Transformation of statistics
NDHIST	N-dimensional histogram
SCTRPL	Scatter Plots
DOTDATA	Dot data file creation
LABEL	Cluster labeling
DAMRG	MSS data merging
GTDDM	Ground truth dot dump (dot labeling)
GTTCN	Ground truth tape conversion

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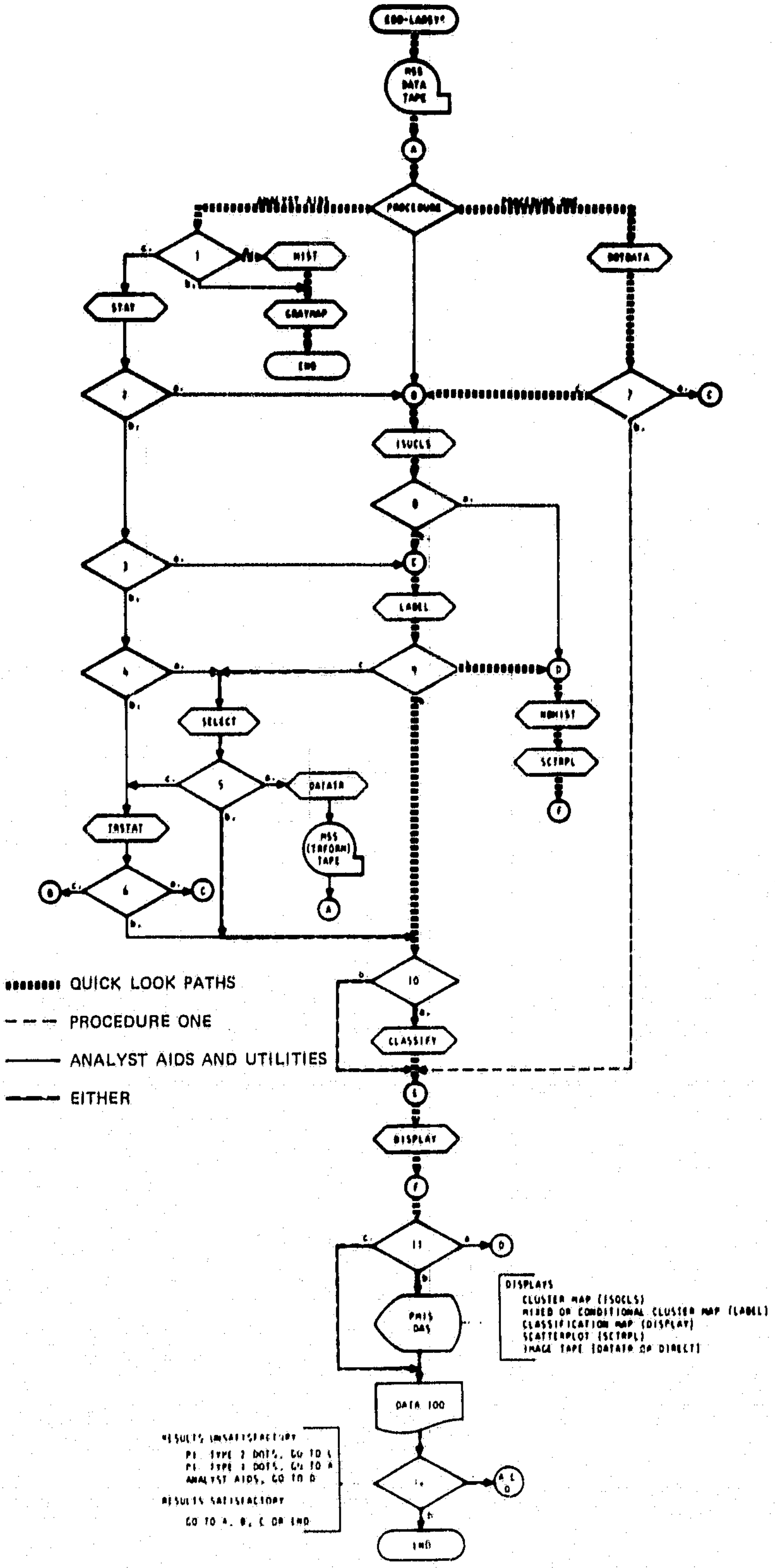
MAJOR PROCESSING PATHS IN EOD–LARSYS



DISPLAYS
CLUSTER MAP (ISOCLS)
MIXED OR CONDITIONAL CLUSTER MAP (LABEL)
CLASSIFICATION MAP (DISPLAY)
SCATTERPLOT (SCTRPL)
IMAGE TAPE (DATAIN OR DIRECT)

RESULTS UNSATISFACTORY
PI TYPE 2 DOTS, GO TO C
PI TYPE 1 DOTS, GO TO A
ANALYST AIDS, GO TO D

RESULTS SATISFACTORY
GO TO A, B, C OR END

3.6 CLUSTERING (CLASSY) STUDY

- Rationale:

  See 3.5

- Objective:

  Gain first indications of how (4 channel) TM data "clusters," i.e.

  - How many clusters will CLASSY find in a typical scene?
  - What is the correspondence between these clusters and various ground cover categories?
  - How do clusters found with TM data compare to those found using MSS data?

- Scope:

  CLASSY was run on Thematic Mapper data for two scenes:

  - Segment 9645 (Tecumseh): Left and right halves of primarily agricultural scene were processed. Current ground truth is available.
  - Segment 231 (former LACIE-TY blindsite): Left half of scene was processed. Left half of August 1980 MSS acquisition was processed for comparison.
  - CLASSY has also been run on 6 and 7 channel simulated TM data from Webster County, Iowa.

- - Clusters appear to correspond well with certain ground cover types: Trees, urban areas, roads, bare soil; single acquisition four-channel TM data does not appear to be able to distinguish between crop types accurately.
  - There appear to be more clusters inherent in single-acquisition TM data than in single acquisition MSS data. When run on the left half of segment 231, CLASSY found 8 clusters with TM data and 5 with MSS.
  - Classes composed of boundary (mixed) pixels may be a problem with TM data in some cases. Such classes are apparent in segment 231, but do not seem to occur in segment 9645.

CLASSY CLUSTER MAP USING TM DATA.

CLASSY CLUSTER MAP USING MSS DATA (AUGUST 1980).

COMPARISON OF CLASSY CLUSTER MAPS USING 4 CHANNEL TM DATA VS. 4 CHANNEL MSS DATA. SEGMENT 231, FULTON COUNTY OHIO. BOTH ARE 2.5 X 3 N.MI. AREAS, BUT ARE NOT REGISTERED WITH EACH OTHER.

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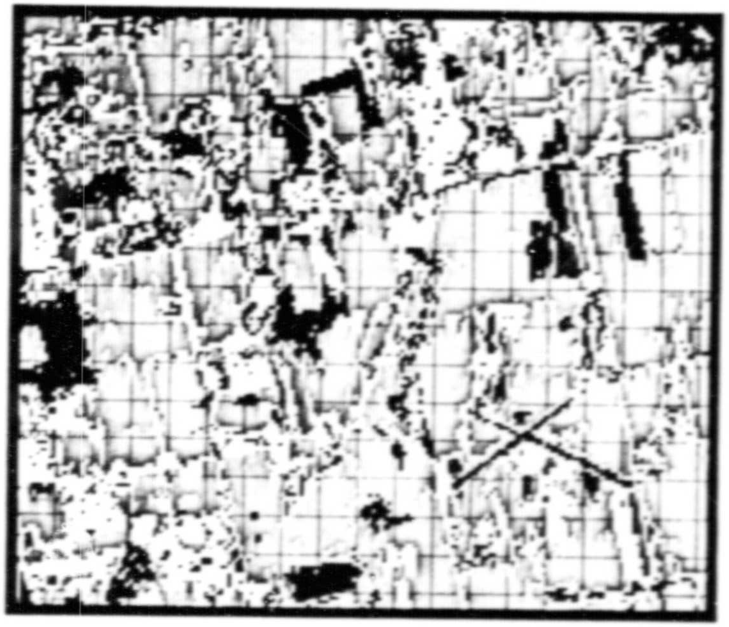
FOUR-CHANNEL TM DATA CLASSY CLUSTER MAP. UPPER LEFT-HAND QUADRANT, SEGMENT 9645 (TECUMSEH), JULY 20, 1982, 2.5 x 3 N.MI.



FOUR-CHANNEL TM DATA CLASSY CLUSTER MAP. UPPER RIGHT-HAND QUADRANT, SEGMENT 9645 (TECUMSEH), JULY 20, 1982, 2.5 x 3 N.MI.

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