General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

AgRISTARS

E83-10427

EW - L3 - 04415

JSC - 18879

CR-171689

Early Warning and Crop Condition Assessment

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

MARCH, 1983

EFFECTS OF DECREASING RESOLUTION ON SPECTRAL AND SPATIAL INFORMATION CONTENT IN AN AGRICULTURAL AREA

SEP 1983
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

*Lockheed Engineering and Management
Services Company, Inc.*

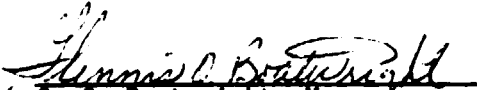Lyndon B. Johnson Space Center
Houston. Texas 77058

1. Report No. EW-L3-04415; JSC-18879	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Effects of Decreasing Resolution on Spectral and Spatial Information Content in an Agricultural Area		5. Report Date June 1983
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. LEMSCO-19352
9. Performing Organization Name and Address Lockheed Engineering and Management Services Co., Inc. 1830 NASA Road I Houston, TX 77258		10. Work Unit No. 008-72-457
		11. Contract or Grant No. NAS 9-17800
12. Sponsoring Agency Name and Address Early Warning/Crop Condition Assessment Project Office USDA, 1050 Bay Area Blvd. Houston, TX 77058 ATTN: V. S. Whitehead		13. Type of Report and Period Covered Technical Report
		14. Sponsoring Agency Code

15. Supplementary Notes The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a joint program of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Dept. of Commerce), the Agency for International Development (U.S. Dept. of State), and the U.S. Dept. of the Interior.

16. Abstract

   This document describes the effects of decreasing spatial resolution from 6 1/4 miles square to 50 miles square. The effects of increases in cell size is studied on; the mean and variance of spectral data; spatial trends; and vegetative index numbers. Also, presented is a summary of information content changes on cadastral, vegetal, soil, water and physiographic information.

17. Key Words (Suggested by Author(s)) Spatial resolution Spectral information Information content	18. Distribution Statement UNLIMITED 43

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 45	22. Price*

JSC Form 1424 (Rev Nov 75)   NASA — JSC
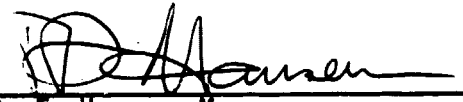
EFFECTS OF DECREASING RESOLUTION ON SPECTRAL AND SPATIAL

INFORMATION CONTENT IN AN AGRICULTURAL AREA

Approved by

USDA

Lockheed-EMSCO

G. O. Boatwright, Manager
Early Warning/Crop Condition
Assessment Project, AgRISTARS
Program

R. F. Hansen, Manager
Early Warning/Crop Condition
Assessment Project, Renewable
Resources Department

iii

PREFACE

The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing is a multiyear program of research, development, evaluation, and application of aerospace remote sensing for agricultural resources, which began in fiscal year 1980. This program is a cooperative effort of the U.S. Department of Agriculture, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration (U.S. Department of Commerce), the Agency for International Development (U.S. Department of State), and the U.S. Department of the Interior.

TABLE OF CONTENTS

FIGURES

vi

TABLES

EFFECTS OF DECREASING RESOLUTION ON SPECTRAL AND SPATIAL INFORMATION CONTENT IN AN AGRICULTURAL AREA

1.0 INTRODUCTION

This comparison considers resolutions ranging between Landsat sized pixels and resolution cells 50 x 50 miles in size. Primary consideration is given to the range of cell sizes between 6 1/4 x 6 1/4 to 25 x 25 miles. The objectives of the comparisons were to determine the kinds of spatial information which is changed through aggregation of pixels in increasingly larger cells, and the nature of the regional trends in spatial information computed for the scene as the cell size changes.

1.1 Approach

1.1.1 Data Input

In this study, an attempt was made to minimize errors in both data registration and atmospheric interference. Assumptions are therefore made which do not consider either of these sources as significantly contributing to the variations in information content which are identified. Only a single Metsat (NOAA-6) data set was analyzed. Landsat data images were used as ancillary, relatively high resolution data, to support the analysis. No Landsat numerical data are included in this study. All numerical (spectral) data in this study are derived from a July, 1980 NOAA-6 acquisition. After considerations of several sites, a Great Plains study site was selected in western Iowa and eastern Nebraska and is referred to as the "Pattowatomie Study Site".

1.1.2 Registration and Data Aggregation Into Nested Cells

A Landsat image, scene (2504-16211) is used to define the limits of the study area. The Metsat data was extracted from the scene such that it corresponds to the Landsat image boundaries. The edited data was then analyzed. No specific correction was made to their spectral content. Because later analyses require input to a Calcomp plotter, geographic grids used in the comparisons were limited to a rectangular shape. A small amount of data along the edges of the scene therefore may be lost.

Data registration is performed manually by establishing large area control points and adjusting a grid of 256 cells (i.e. 16 x 16) to the overall Landsat scene. Cells in this (Level 1) grid correspond approximately to 6 1/4 x 6 1/4 miles on the ground. Each cell consists of 15 columns by 10 rows, or 150 Metsat (NOAA-6) pixels. A program referred to as PATCH-1 portions, sums and averages cells at each level specified by the user. The PATCH-1 program provides a method for adjusting cells to any desired size equally across an area. It progresses through two subsequent aggregation steps, doubling the size of the cell in each direction thereby quadrupling cell area in each step. The program prints out a three level gridded network of means and standard deviations for each Metsat

channel and in addition, with slight modification, will compute any
vegetatie index utilizing the two channel inputs. The vegetative
index is also printed in a grid cell format. Figure 1-1 A and B
and illustrates a sample output.

In PATCH-1 output, cells have positional meaning relative to each
other only. They do not have positional accuracy with respect to
any geographic coordinate system. A program to interface the
PATCH-1 numerical output with a Calcomp plotting routine was
developed, but not tested.

Each 15 x 10 (i.e. Level 1) Metsat-pixel cell corresponds,
approximately, to 6 1/4 by 6 1/4 nautical miles on the ground.
Level 2 cells, that are 30 x 20 pixel cells correspond to 12 1/2 x
12 1/2 nautical mile cells, and Level 3 corresponds to 25 x 25
nautical mile cells. Once the initial manual registration of the
Level 1 grid is established, the other two levels are registered
with equal accuracy.

1.2 Analysis

The analysis performed on the data was a comparasion of spatial trends
in the raw data and in relevant physical and statistical parameters.
Subsequent to this study, a comparison of the trends in the temporal
dimension is planned. Thus, spatial changes in spectral data input
was assessed.

1.2.1 Trend Analysis

Information derived from a trend surface, that is in areal samples
of geographic information, is a function of the content of the
original input data. The quality of information in the trend
surfaces examined here was controlled directly by the information
inherent in the original Metsat pixels. In this study, the Metsat
pixel aggragation performed by PATCH-1 is a grid generalization
technique of trend mapping. The grid generalization technique
averages the original data over an area to create a new set of
values. The network of new values creates areal cells in which
each pixel contained therein contributes information over a wider
area.

In the original Metsat data, each pixel contributes information
only for the ground area it covers and values outside of the
corresponding area on the ground are not affected. An analyst must
view the overall image in order to establish trends in physical
parameters on the ground. Typically, the overall image contains
information (i.e. "noise") that is non-essential to the overall
trend.

D A T A   S U M M A R Y

CHANNEL   1   M E A N S

          LEVEL 1   LEVEL 2   LEVEL 3

FIELD= 1ACQ= 1

```
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆ 12.◆ 11.◆ 11.◆ 10.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   11.  ◆   10.  ◆ ◆                   ◆
◆ 12.◆ 11.◆ 10.◆ 10.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆        11.        ◆
◆ 11.◆ 12.◆ 11.◆ 10.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   11.  ◆   10.  ◆ ◆                   ◆
◆ 11.◆ 11.◆ 11.◆ 10.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
```

                              S T D S

```
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆ 1.0◆ 1.0◆ 1.1◆ 1.3◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   1.1  ◆   1.3  ◆ ◆                   ◆
◆ 0.9◆ 0.8◆ 1.2◆ 1.4◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆        1.4        ◆
◆ 1.8◆ 2.4◆ 0.8◆ 1.7◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   1.8  ◆   1.2  ◆ ◆                   ◆
◆ 1.0◆ 0.8◆ 0.7◆ 0.8◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
```

CHANNEL   2   M E A N S

          LEVEL 1   LEVEL 2   LEVEL 3

FIELD= 1ACQ= 1

```
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆ 17.◆ 14.◆ 14.◆ 14.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   16.  ◆   14.  ◆ ◆                   ◆
◆ 16.◆ 15.◆ 14.◆ 13.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆        15.        ◆
◆ 15.◆ 17.◆ 15.◆ 13.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   15.  ◆   14.  ◆ ◆                   ◆
◆ 15.◆ 15.◆ 15.◆ 14.◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
```

                              S T D S

```
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆  ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆ 0.9◆ 1.7◆ 1.5◆ 2.5◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   1.4  ◆   1.9  ◆ ◆                   ◆
◆ 1.0◆ 0.9◆ 1.4◆ 1.4◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆        2.0        ◆
◆ 3.1◆ 2.5◆ 0.9◆ 1.6◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆   2.3  ◆   1.4  ◆ ◆                   ◆
◆ 1.4◆ 1.1◆ 1.0◆ 1.1◆ ◆           ◆        ◆ ◆                   ◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
```

Figure 1-1A.   PATCH 1 Data Summary for 2 channel Metsat data.

LEVEL 1　　　　　LEVEL 2　　　　LEVEL 3

FIELD= 1ACQ= 1

```
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦
♦ 4.6♦ 3.8♦ 3.5♦ 3.5♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦    4.3 ♦     3.3 ♦ ♦                     ♦
♦ 4.4♦ 4.5♦ 3.9♦ 2.6♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦        3.9          ♦
♦ 4.0♦ 4.6♦ 4.5♦ 3.3♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦    4.2 ♦     3.9 ♦ ♦                     ♦
♦ 4.1♦ 4.2♦ 3.9♦ 3.9♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦
```
VIN OPTION 1

LEVEL 1　　　　　LEVEL 2　　　　LEVEL 3

FIELD= 1ACQ= 1

```
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦
♦ 0.2♦ 0.2♦ 0.1♦ 0.1♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦    0.2 ♦     0.1 ♦ ♦                     ♦
♦ 0.2♦ 0.2♦ 0.2♦ 0.1♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦        0.2          ♦
♦ 0.2♦ 0.2♦ 0.2♦ 0.1♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦ ♦    0.2 ♦     0.2 ♦ ♦                     ♦
♦ 0.2♦ 0.2♦ 0.2♦ 0.2♦ ♦           ♦           ♦ ♦                     ♦
♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦  ♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦
```

Figure 1-1B. PATCH-1 Summary Data for VIN Options

The effect of the grid generalization technique is twofold. First, it tends to dampen the spectral effects of local anomalies in the scene which contain nonessential information to crop condition, and second, it allows the user to separate local anomalies from the overall regional trends. Depending on the degree of grid general-ization, the analyst may expect the spectral details of the scene to be reduced eventually beyond actual detection. At a satisfac-tory level of generalization, a subjective selection of grid size is made which provides the user with the regional trend information desired. The level selected is a function of need. Too great a generalization may completely subdue trends desired, while too little generalization foregoes regional trends and characterizes local anomalies. It is common in geographic information studies that different levels of generalization are needed to obtain the same information in different geographic regions. Each higher level of generalization may be viewed as a "filter", sequentially eliminating local geographic information at each level, and allowing increasingly broader regional information through.

1.2.2 Parameters Examined

The analysis systematically considers the raw spectral data channels individually and jointly. Both the mean and the variance in the data are examined. Two kinds of variances are analyzed - the variance between cells means, and variance internal to the cells. In addition, the Gray-McCrary Index (GMI)* is examined at the three levels of resolution. All the data are compared on summary graphs to aid in the understanding of the trends.

1.3 Pottawatomie Study Area

Appendix A contains a detailed description of the Pottawatomie Study Area. In general, the area represents much of the midwest Great Plains agricultural region in the early part of the growing season.

Physiographic features which should be noted at this point include the following:

a. The alluvial valley of the Missouri River running diagonally across the scene and the many tributary rivers, particularly the Platte River located in the southwest quadrant of the scene.

b. The district spectral contracts between alluvial and glacial till soils (southeast quadrant) and upland Prarie Loess soils.

c. A portion of the Des Moines River Basin located in the northeast portion of the scene.

Similarly, an understanding of vegetative distributions is important in the following discussions and the following characteristics were noted in the study area:

*also known as the Environmental Vegetation Index (EVI)

a. Approximately 30 percent of the study area is covered with vegeta-
tion (undifferentiated) in the acquisition used in the analysis.

b. The greatest vegetation density occurs in the deciduous Hickory-
Oak forest area (approximately 8 percent of the study area) which
occurs mainly along the steep ridges of alluvial valleys.

c. Corn and soybeans fields are plowed and have been planted but not
yet emerged. They are distributed rather uniformly over the
Praria Loess soils. More soybeans are grown on the alluvial soils
than corn.

d. A small percentage of the vegetated area consists of unimproved
pasture, oats, alfalfa and clover, all of which have emerged.

Landuse in the study area is dominated by farmland, consisting of about 90
percent of the area. About 2 percent of the area is urban and about 8
percent deciduous forest. Table 1-1 summarizes the approximate
distribution of soils, green vegetation, and landuse.

TABLE 1-1. SUMMARY OF SOIL AND VEGETATION DISTRIBUTION

	Percentage of Total Scene[1]	Stage of Growth	Distribution in Scene
Soils Type			
Prairie Loess Total	65		Uniform (topographic high)
Bare % of Total	(70)[2]		
Alluvium and Till Total	35		Restricted to fluvial basins (topographic lows) and S. E. Quadrant
Bare % of Total	(90)[2]		
Green Vegetation			
Undifferentiated	30		Uniform
Deciduous (Forest)	10		Restricted[3]
Cropland (Herbaceous)	20		Uniform[4]
Land Use			
Agricultural Farmland	90		Uniform
Corn	45-55	Planted	Mainly Prairie Soils
Soybeans	25-30	Planted	High % on Alluvium
Oats		Emerged	Uniform
Alfalfa	4-9	Emerged	Uniform
Clover		Emerged	Uniform
Unimproved pasture	5-10	Emerged	
Urban and Roads	2		Restricted[3]
Other (mainly deciduous forest)	8		Restricted[3]

[1]From Landsat data and ancillary agricultural reports

[2](%) of total soils

[3]Steep slopes and river bottoms

[4]Mainly Prairie soils

2.0 COMPARATIVE ANALYSIS OF SPECTRAL RESPONSE

This analysis first considers the numerical changes measured in the mean and variance of the two individual Metsat channels at each resolution level. A discussion follows which illustrates the resulting spatial changes and trends. Similar analyses are performed on the combined two channel response, and the Gray-McCrary Vegetative Index (i.e. Channel 2 minus Channel 1).

2.1 Overall Scene Mean and Variance

Figure 2-1 illustrates visible band and infrared band histograms computed for the overall Metsat scene which contains the smaller, study area actually examined in this study. Means and variances were estimated for both the overall scene and the study area and the comparison is made in Table 2-1.

Table 2-1. Mean and Variance - Overall Scene vs. Study Area				
	Visible		Infrared	
	$\bar{x}$	s^2	$\bar{x}$	s^2
Overall Metsat Scene	8	2.0	16	2.5
Study Area	9	1.5	14	2.1

The infrared values display a typical bell-shaped histogram, the visible band data is highly skewed. Because its shape approximates a normal Gaussian cu e, r ich of the succeeding discussions uses the infrared distribution rather than the visible band data.

The statistical differences between the overall scene statistics and the study area statistics were not measured. Differences are attributed to different percentages of soil types and vegetation types. Skewness in the visible band curve may be related to the high percentage of dark alluvial soil in the scene and the spring growth of dark green vegetation. The green vegetation in the infrared band shifts the curve upward, creating the bell shaped shown.

In comparison with the overall scene, the small differences in spectral statistics computed for the study area suggest that the latter is representative of the larger area. For the purpose of later discussions, the study area means of 9 (visible) and 14 (infrared) should be noted.
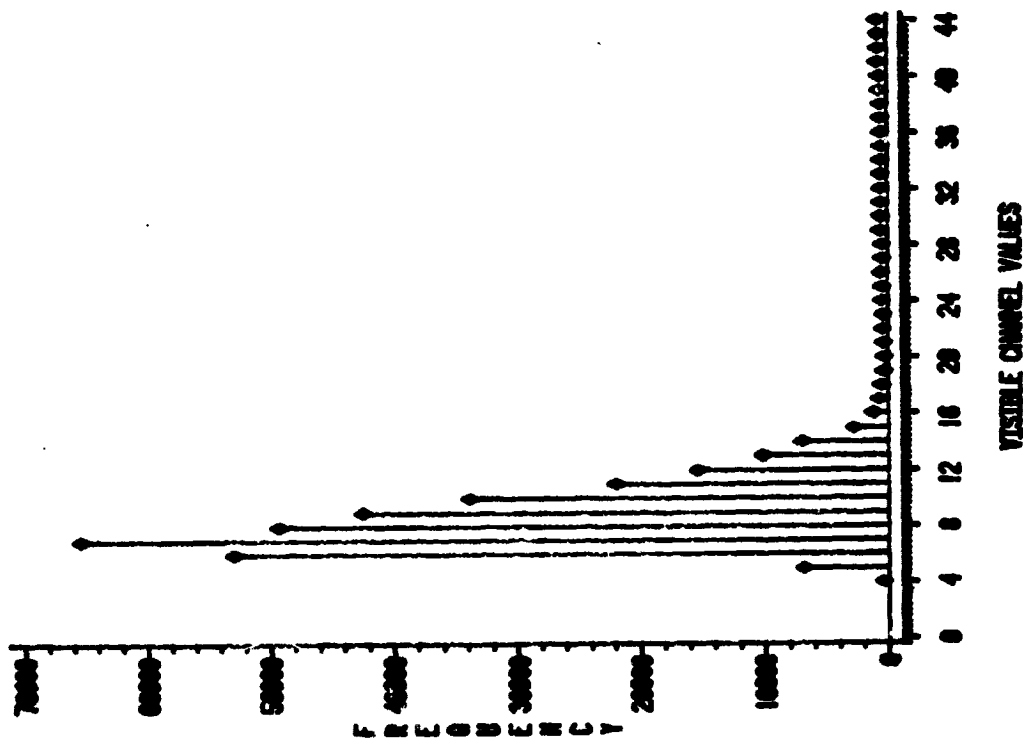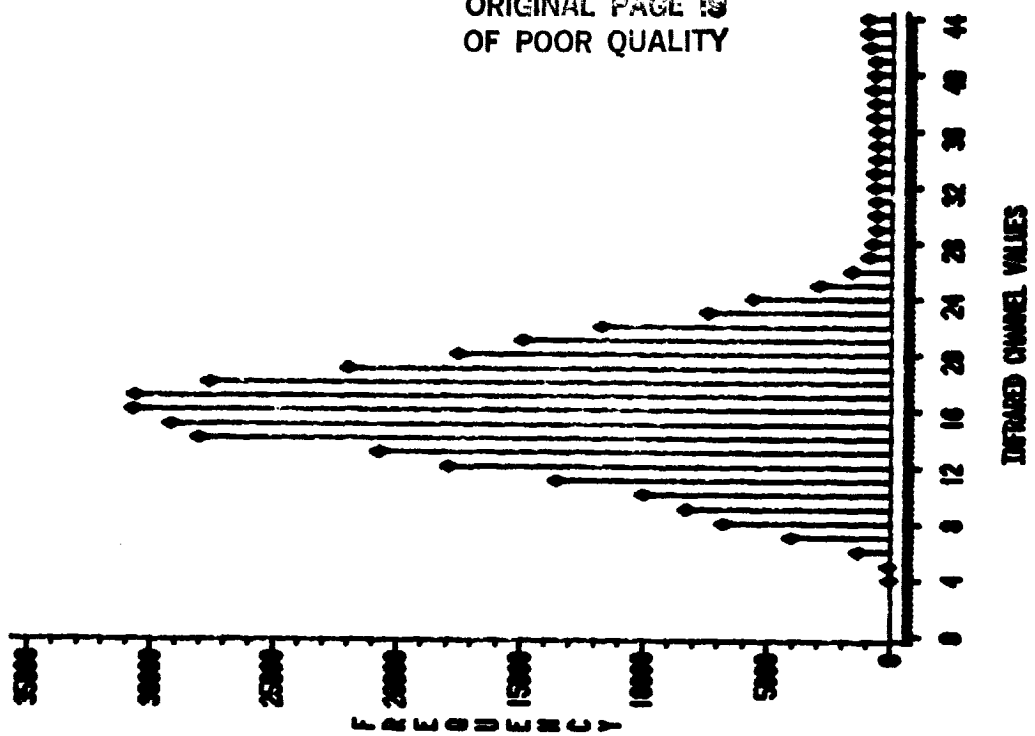
Figure 2-1. Histograms of Metsat Scene

2.2 Effect of Increases in Cell Size on Mean and Variance

Spatial variance is a quality inherent to most geographic landscapes. The mean spectral value at any scale or resolution, therefore, is an estimate of the total range of spectral values within the sampled cell. The greater the variance within a cell, the less representative the mean value is of any particular point on the ground selected at random within the sampled cell. It follows therefore, that cells with high variances provide the analyst with mean values that are <u>less</u> representative of the total cell area, than do cells with low variances. It also follows that without a measure of variance, an analyst cannot estimate the reliability and spatial applicability of a mean value.

Two effects of increasing cell size are measured in the study area data. These inlcude:

a. an increase in <u>within</u> cell variance as cell si:e increases and

b. a corresponding decrease in <u>between</u> cell variance as cell size increases.

These effects are illustrated in Figures 2-2 and 2-3. Figure 2-2 plots the high and low infrared spectral values for varying cell sizes. As cell size increases, approaching the 100 by 100 mile study area size. The <u>range</u> of cell means decreases from seven units at Level 1 to two units at Level 3. Thus, the mean values estimated for any cell approaches, and finally reaches, 14, the study area mean, at the 50 by 50 mile cell size.

The decrease in the range of mean values is indicative of the decrease in <u>between</u> cell variance. That is, as cell size increases, mean values come closer to each other. But, it also follows from Figure 2-2 that as the range in mean values decreases, more and more spectral variance is "packed" into each value. That is, <u>within cell</u> variance is increasing correspondingly.

Figure 2-3 shows two measures of the average within cell variance. Variance was measured for each cell, at each level of resolution, then averaged by resolution level. In Figure 2-3A the average variance as estimated by S^2, the square of the standard deviation, for Level 1 equalled 2.0, and increased to 4.0 for the entire study area. In Figure 2-3B, the coefficient of variation (CV) increased correspondingly from 10 percent to slightly more than 14 percent. Strictly understood, the increase in variance in 2-3A is only suggestive of the trend. Because of the differences in cell sample size, the S^2 cannot be analytically compared as shown. Figure 2-3B, however, is the standard deviation (SD) expressed as a percentage of the mean ($\bar{x}$) and this ratio can be compared.

It is significant that the within cell variance of 25 square mile cells nearly equals that of 50 square mile and 100 square mile cells. This trend, when considered in concert with the trend in Figure 2-2, strongly suggests that the information derived at the Level 3 (25
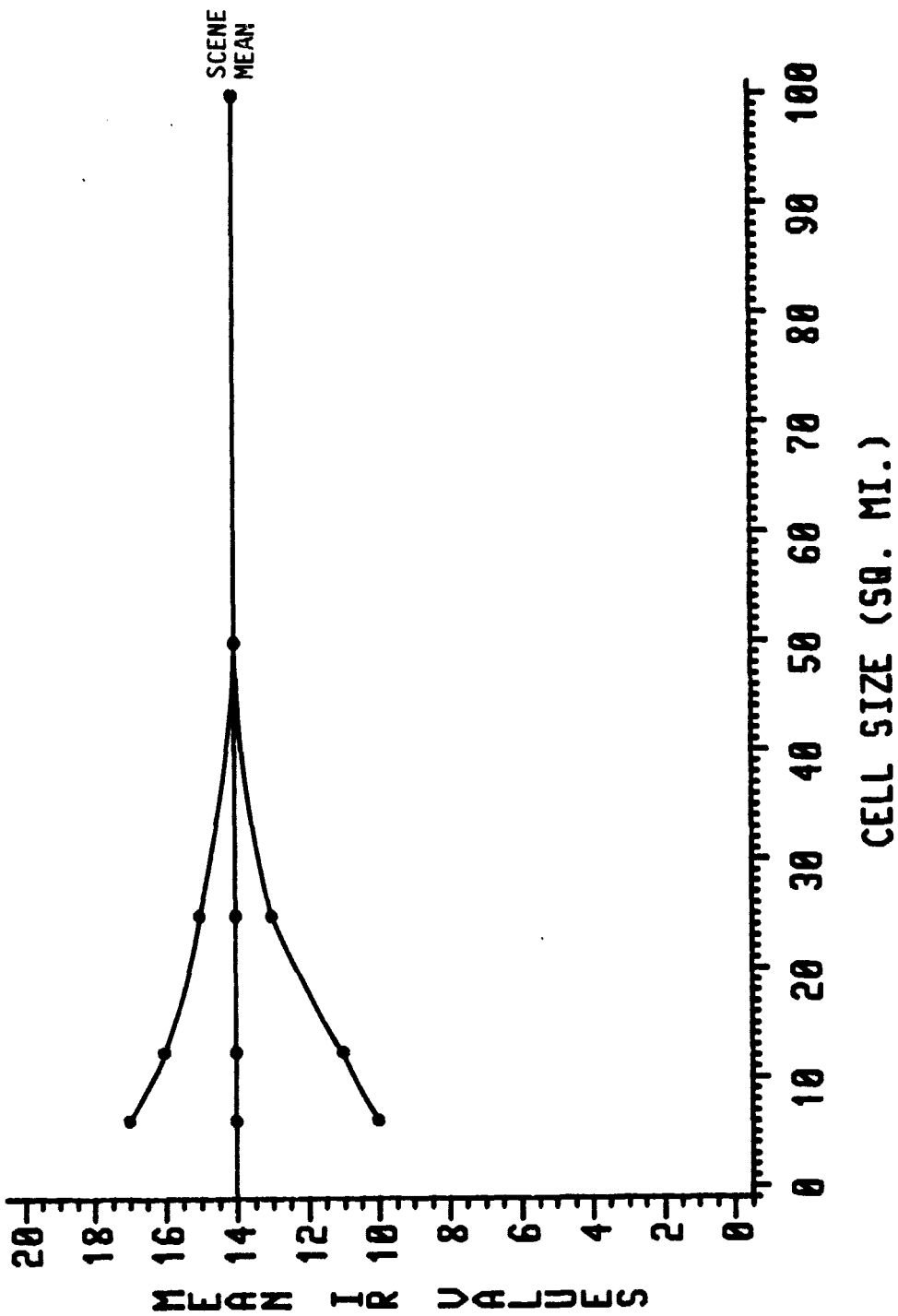
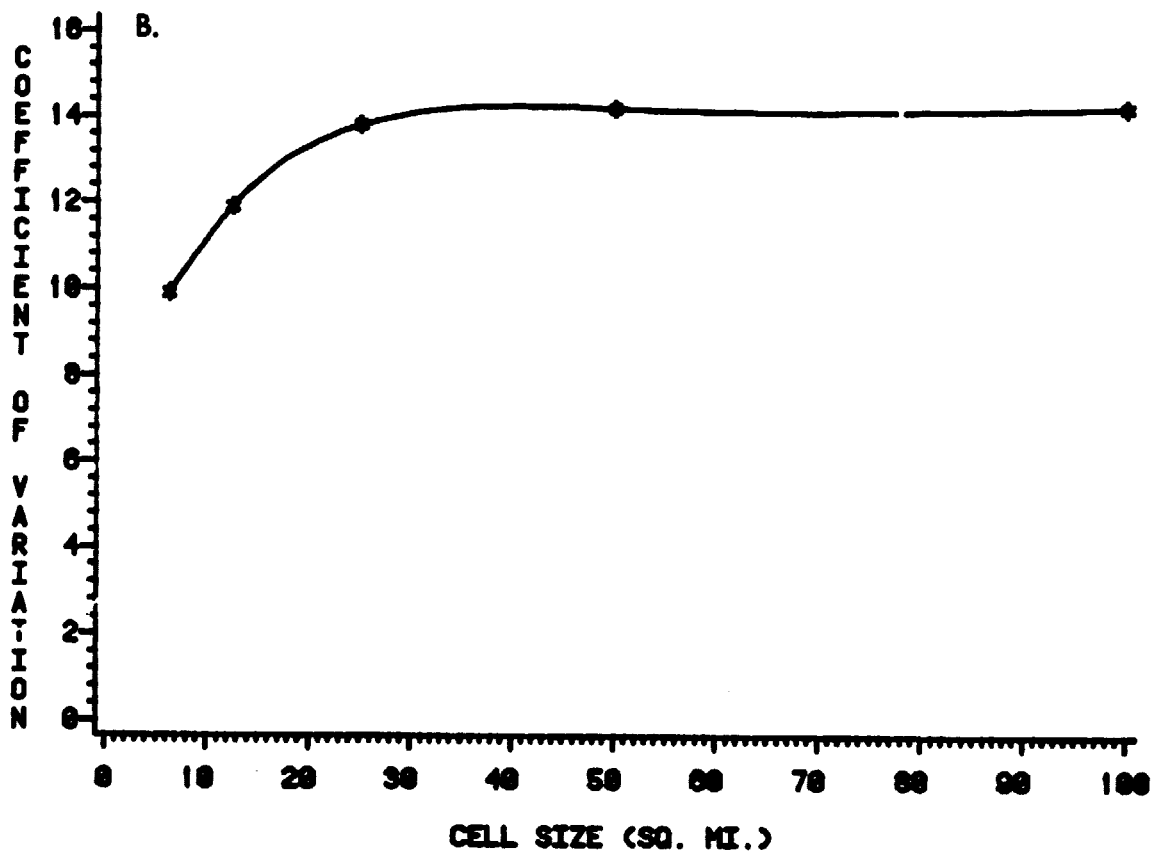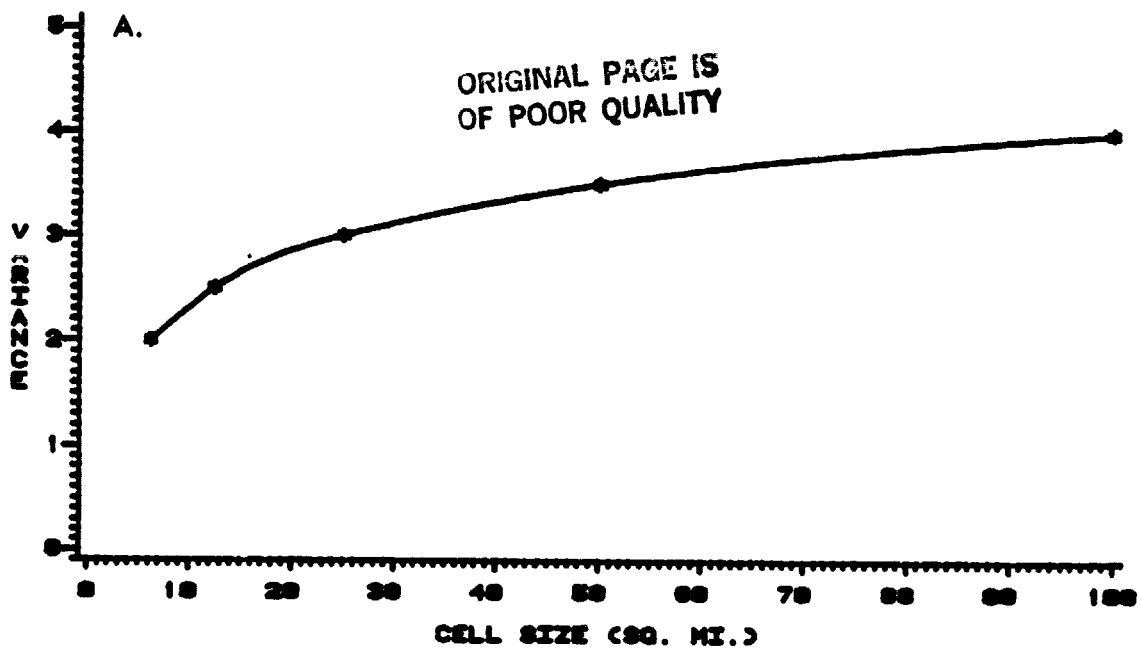Figure 2-2. Range in Mean Infrared Cell Values.

Figure 2-3. Average Variation as Function of Cell Size.

square mile) is nearly identical to that which would be derived at the 50 square mile or 100 square mile cell size.

2.3 Effect of Increases in Cell Size on Spatial Trends

The previous section has shown the effects of increasing cell size on the mean and variance of the spectral values. The trends in mean and variance values manifest in an information "filtering effect" which can be expressed spatially.

Figure 2-4 shows the "filtering" effect of increasing resolution cell size. The left column represents the visible band data and the right column, the infrared band data. The top two maps are the contoured mean values from cells 6 1/4 by 6 1/4 miles in size and the middle and bottom two represent the 12 1/2 x 12 1/2 mile, and the 25 x 25 mile, cell sizes respectively.

In the comparative process, it was noted that in these data the mean visible value of 10 and the mean infrared value of 14 approximated the boundary between alluvial/glacial till soils and the Prairie Loess soils. (Note: the author does not suggest here that this holds true universally or even locally in different data sets. These values were selected arbitrarily for their instructive potential.) In Figure 2-5, all values above 10 and 14 in the two channels are stripped whereas values below have no pattern. This figure is used in conjunction with 2-4 to summarize the following conclusions about spatial trends in the mean values:

1. The "filtering" effect results in lesser spatial detail as resolution decreases in both channels.

2. Both visible and infrared channels vary similarily spatially.

3. Contour patterns of gorund conditions deteriorates between the 12 1/2 x 12 1/2 mile cell and the 25 x 25 mile cell.

4. Major physiographic characteristics of the terrain are detected at 25 x 25 mile cell sizes and may have significance in a large area region.

5. During the early summer/late spring time period, basic information categories appear to be linked to major physiographic units of the landscape.

Control of the physiography is illustrated in virtually every parameter which is examined. Thus, the "filtering" of a physiographic unit of this magnitude was considered as a "deteriorating" characteristic in the regional trend of the parameters examined. Whereas the Missouri River alluvial valley is recognizable by virtue of its geographic position and shape up to the 12 1/2 x 12 1/2 mile cell, its shape and position are not clearly depicted at the 25 x 25 mile cell size. Similarly, the variance displays a highly correlated distribution at the 6 1/4 x 6 1/4 and the 12 1/2 x 12 1/2 cell sizes and highly degraded correspondence at the 25 x 25 mile cell size.
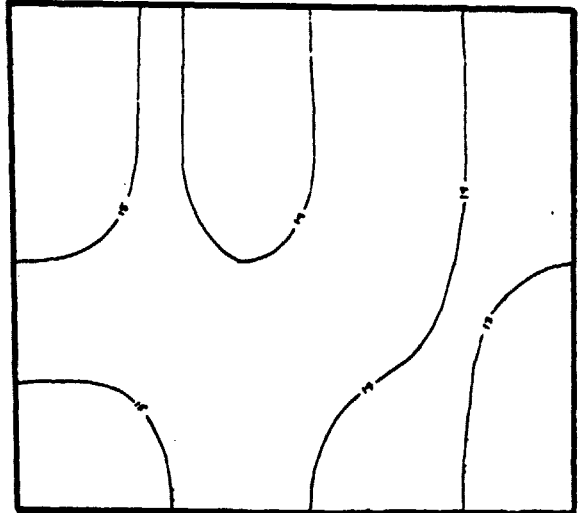
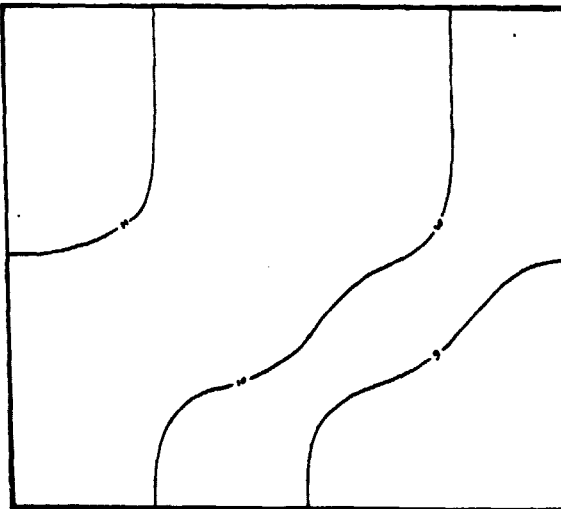VISIBLE   INFRARED

A. 6 1/4 x 6 1/4 MILE CELLS
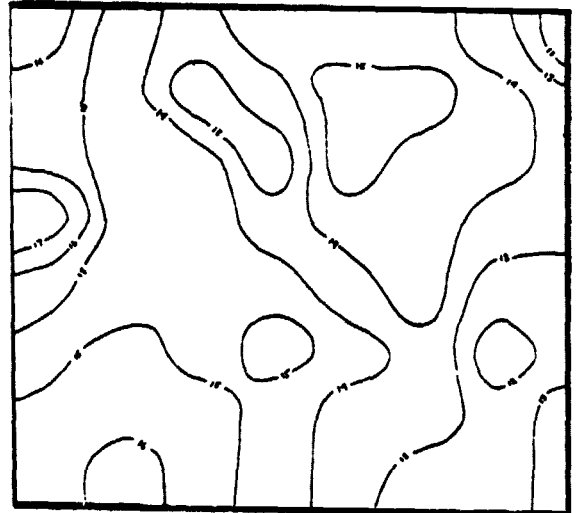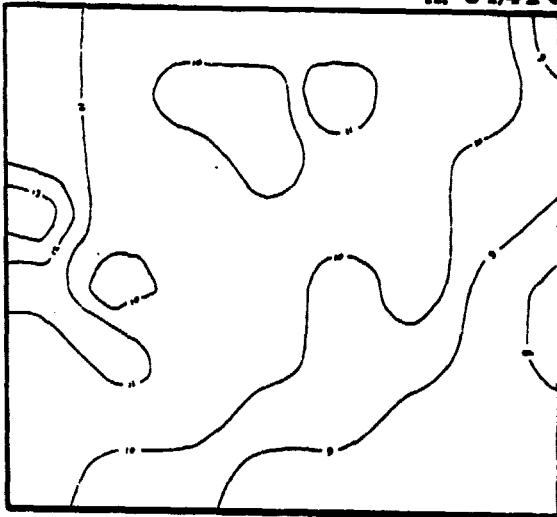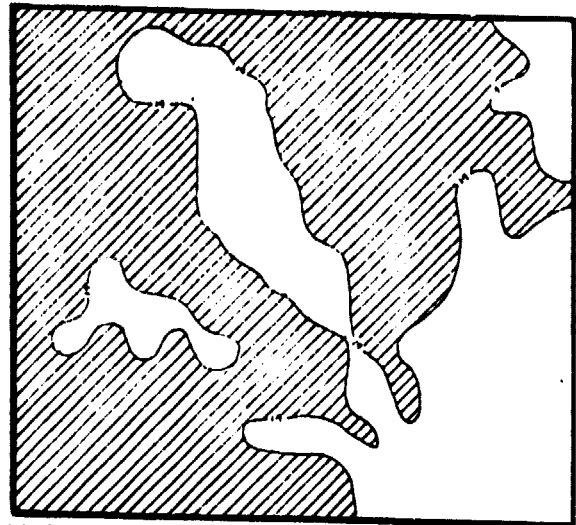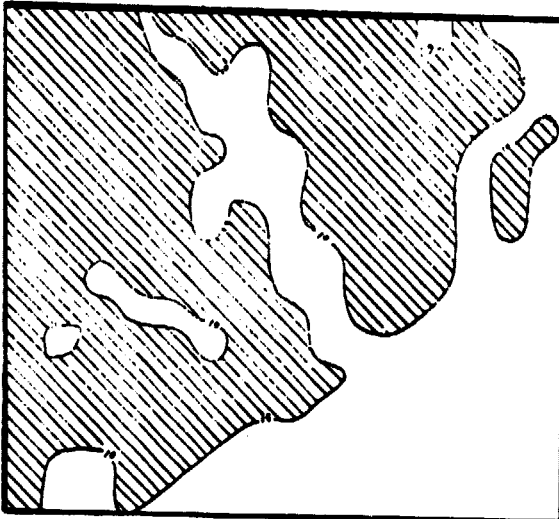
B. 12 1/2 x 12 1/2 MILE CELLS
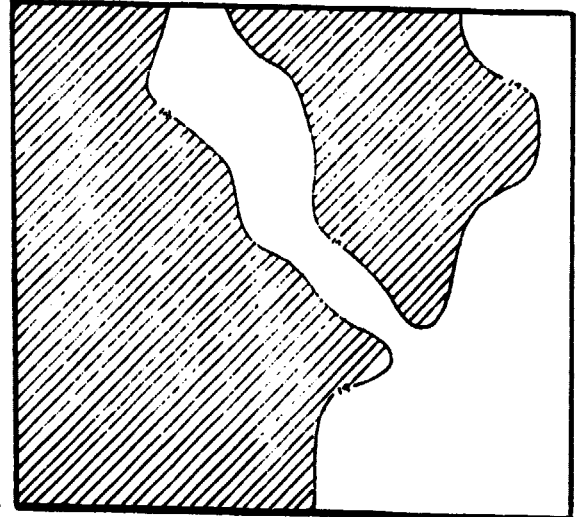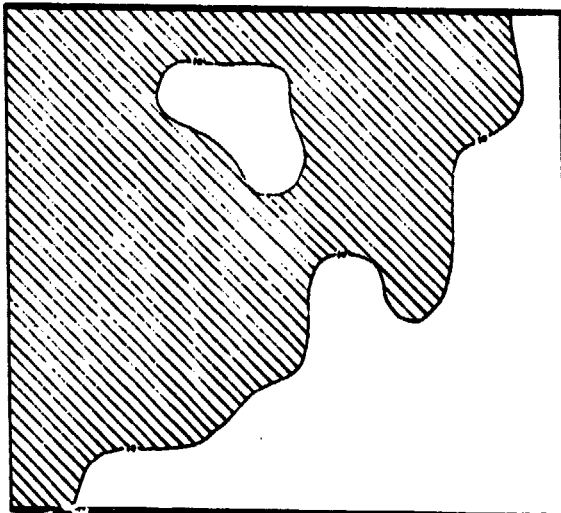
C. 25 x 25 MILE CELLS

Figure 2-4.   Comparison of Visible (left) and Infrared (right) Mean
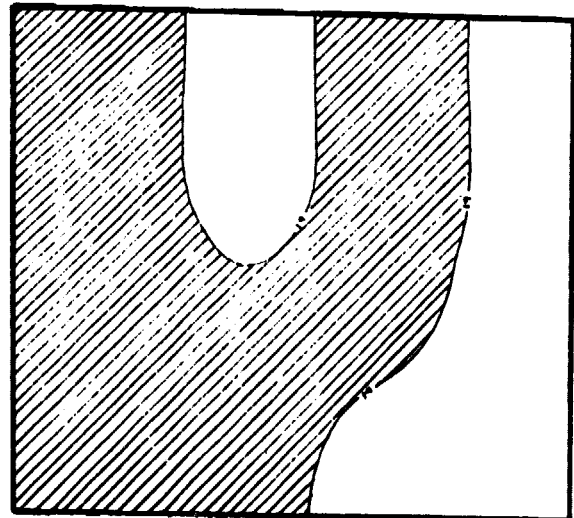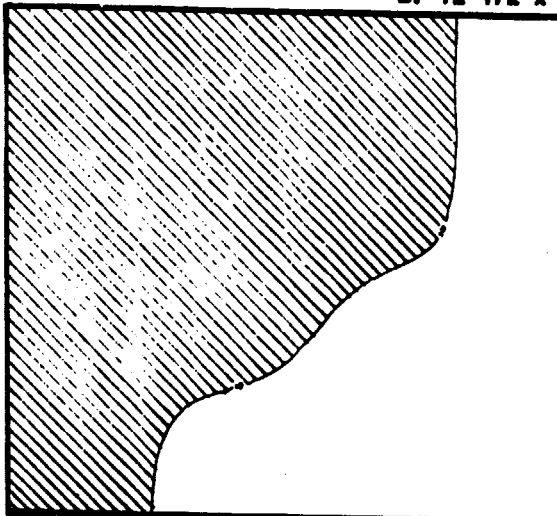Cell Values Between 6 1/4 x 6 1/4 and 25 x 25 mile cells.

VISIBLE   INFRARED

A. 6 1/4 x 6 1/4 CELL SIZE

B. 12 1/2 x 12 1/2 CELL SIZE

C. 25 x 25 CELL SIZE

Figure 2-5.   Comparison of Visible (left) and Infrared (right) Spatial
Patterns Above and Below 10 and 14, Respectively.

Figure 2-6R illustrates the distribution of the coefficient of
variation in the study area for the 6 1/4 x 6 1/4 cell size. In this
illustration only the 10 percent contour line is plotted. Shaded
areas in figure 2-6B correspond to a CV less than 10 percent, and
unpatterned areas represent a CV greater than 10 percent.

Two conclusions may be drawn from Figure 2-6. First the distribution
of the within cell variance at this cell size closely corresponds to
physiographic distribution of the alluvial soils shown in Figure
2-6A. Second, within cell variance is greater (i.e. up to 20 percent)
in the alluvial and glacial till areas than in the Prairie Loess and
soil areas (i.e. 4 to 8 percent). The second conclusion strongly
suggests that a priori stratifications of the landscape by physio-
graphic unit would aid in depicting spectrally derived parameters.

A comparison of the within cell variance, estimated by the square of
the standard deviation, is also illustrated in Figure 2-7 for all
three cell sizes over the study area. Shaded areas in the figure re-
present all values exceeding a variance of 3.0. The same conclusions
drawn in the previous paragraph apply, and in addition, the deterior-
ation of the shape and position of the Missour River Valley is evident
at the 25 x 25 mile cell size. The association between physiography
and within cell variance at the 25 x 25 mile cell size is no longer
apparent.

Understood in another way, the within cell variance in the 25 x 25
mile cells is nearly equal, regardless of physiography. The conclu-
sion is contrary to the results obtained at smaller cell sizes and the
regional trend depicted cannot be easily associated with actual ground
conditions. The "regional" trend shown on the 25 x 25 mile map may be
indicative of a broader scoped trend which is simply not apparent in a
study area of the size used here.

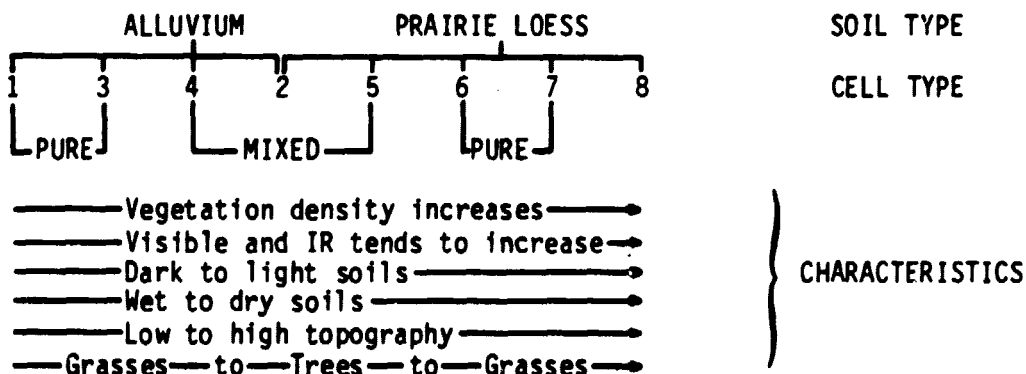## 2.4 Effect of Increase in Cell Size on Combined Channel Response

To characterize the similarity and differences between cells - that is
to examine the between cell variance, all the cells for each level
were plotted on a two-channel scattergram such as is shown in Figure
2-8. Visible band and infrared band spectra are plotted on the "y"
and "x" axis, respectively. The position of each point in the
scatterplot is located and the total number of cells for that position
is shown.

The scatterplot was subjectively partitioned by relating the combined
values to particular environmental conditions on the ground. Table
2-2 lists eight categories which were described in terms of the
information categories described at the beginning of the sections.
The approximate visible and infrared means for each category is also
shown.

In general, the most fundamental partitioning was related to soil
types of which three types were discriminated. The partitioning of
alluvial/till, Prarie Loess and "mixed" cells is shown in Figure 2-9.
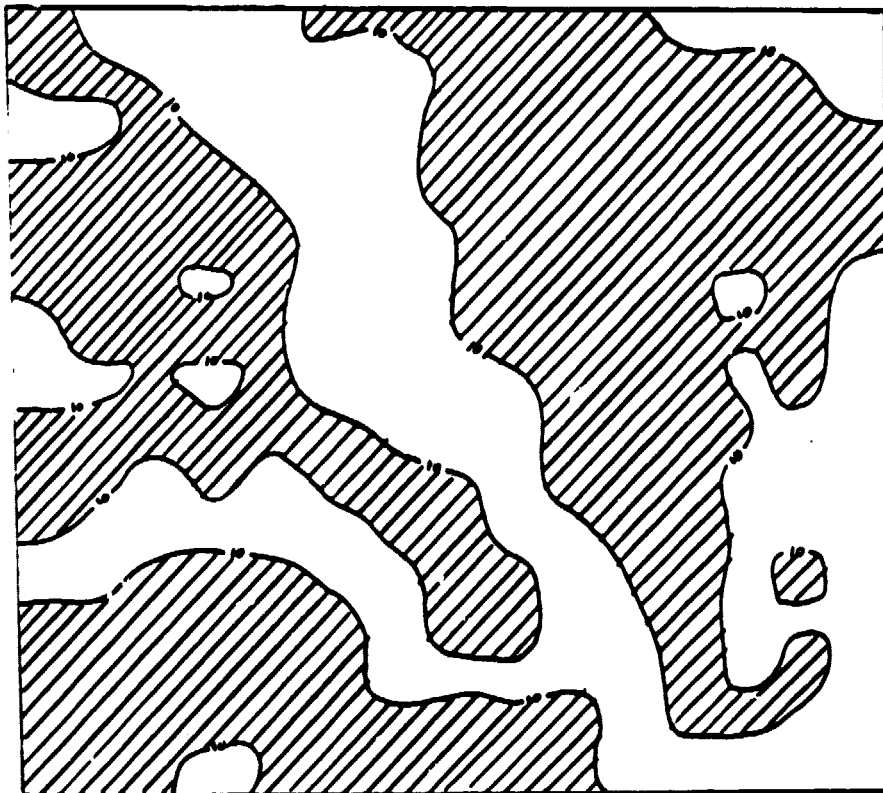The alluvial/till soils always displayed the lowest values in one or

2-9

TABLE 2-2. DESCRIPTION OF CELL CONTENTS IN PARTITIONS

CONTENTS OF 6 1/4 X 6 1/4 CELL TYPES

| CELL TYPE	MEAN V/IR	DESCRIPTION OF CELL CONTENTS
1	7.5/10.5	Nearly level river valley clays and silts. Alluvial soils 80 - 90% bare. Sparse agricultural vegetation in early and mid-June. Cell may contain river water. Soils may have a high water content. Agriculture is intensive.
3	9.0/11.5	River valley clays and silts. Nearly level, 70 - 80% bare soils. Close to Type 1 spectrally. Intensive agriculture with greater density of vegetative cover. Possible water in cells and dark soils.
2	8.0/12.0	Mixture of river valley clays and Prairie loess soils. Vegetation may be Oak-Hickory deciduous forest (50 %) along the perimeter of the river valley or intensive agriculture with sparse vegetative cover. Slopes may be steep to moderate.
4	10.0/13.0	Cells contain the highest density of deciduous trees and are a mixture of alluvial and Prairie loess sols. Cells may contain agricultural land, primarily on alluvium.
5	8.5/15.0	Cells are mainly agricultural fields on Prairie loess soils. Similar to Type 2 cells, but less effect of alluvial soils, fewer drainage systems and some deciduous trees.
6	10.0/15.0	Prairie loess soils. Gently sloping to moderately steep (2-18%), light in color. Intensive agriculture, 50 - 60% bare. Few tree stands. Most common class.
7	11.0/16.5	Same as Type 6, but denser stands of vegetative cover. Agriculture intensive. Perhaps more advanced physiologically than vegetation in Type 6. Small percentage of cells.
8	14.5/19.0	Either bright bare Prairie loess soils or clouds

```
        ALLUVIUM          PRAIRIE LOESS          SOIL TYPE
   ┌────────┬────────┬────┬──────┬──────┬──────┐
   1    3      4      2    5      6      7     8  CELL TYPE
   └PURE┘           └─MIXED─┘    └PURE─┘

   ─────Vegetation density increases────▶
   ─────Visible and IR tends to increase─▶
   ─────Dark to light soils─────────────▶
   ─────Wet to dry soils────────────────▶      CHARACTERISTICS
   ─────Low to high topography──────────▶
   ─Grasses──to──Trees──to──Grasses──▶
```

Figure 2-6. Comparison of Coefficient of Variation Within 6 1/4 x 6 1/4
Mile Cells (b) and the Distribution of Alluvial Soils (a).

B. 12 1/2 CELL SIZE
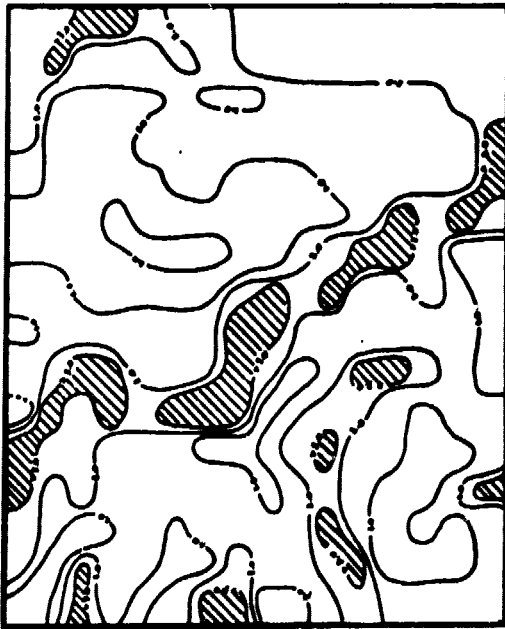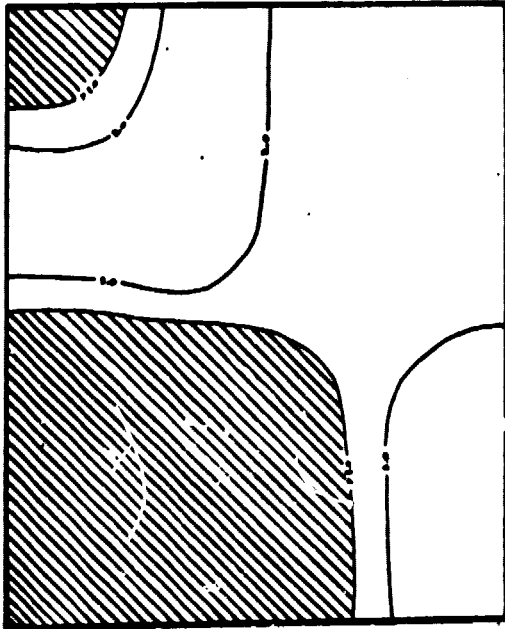
A. 6 1/4 CELL SIZE

C. 25 CELL SIZE

Figure 2-7. Comparison of the Within Cell Variance in the Study Area Infrared Values.
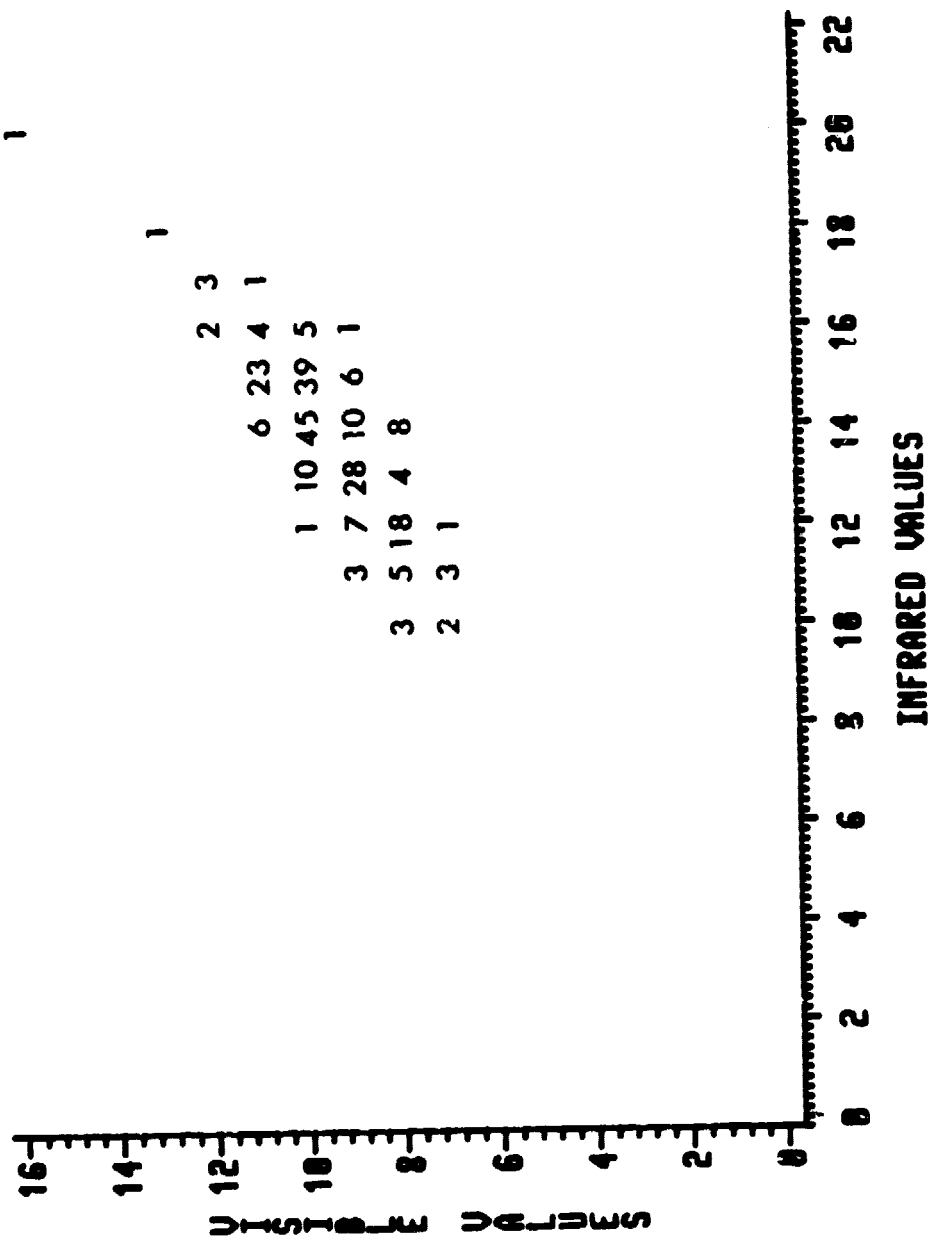
VISIBLE/INFRARED SCATTERPLOT

Figure 2-8.   Scatterplot of All 6 1/4 x 6 1/4 Mile Cells in the Study Area.
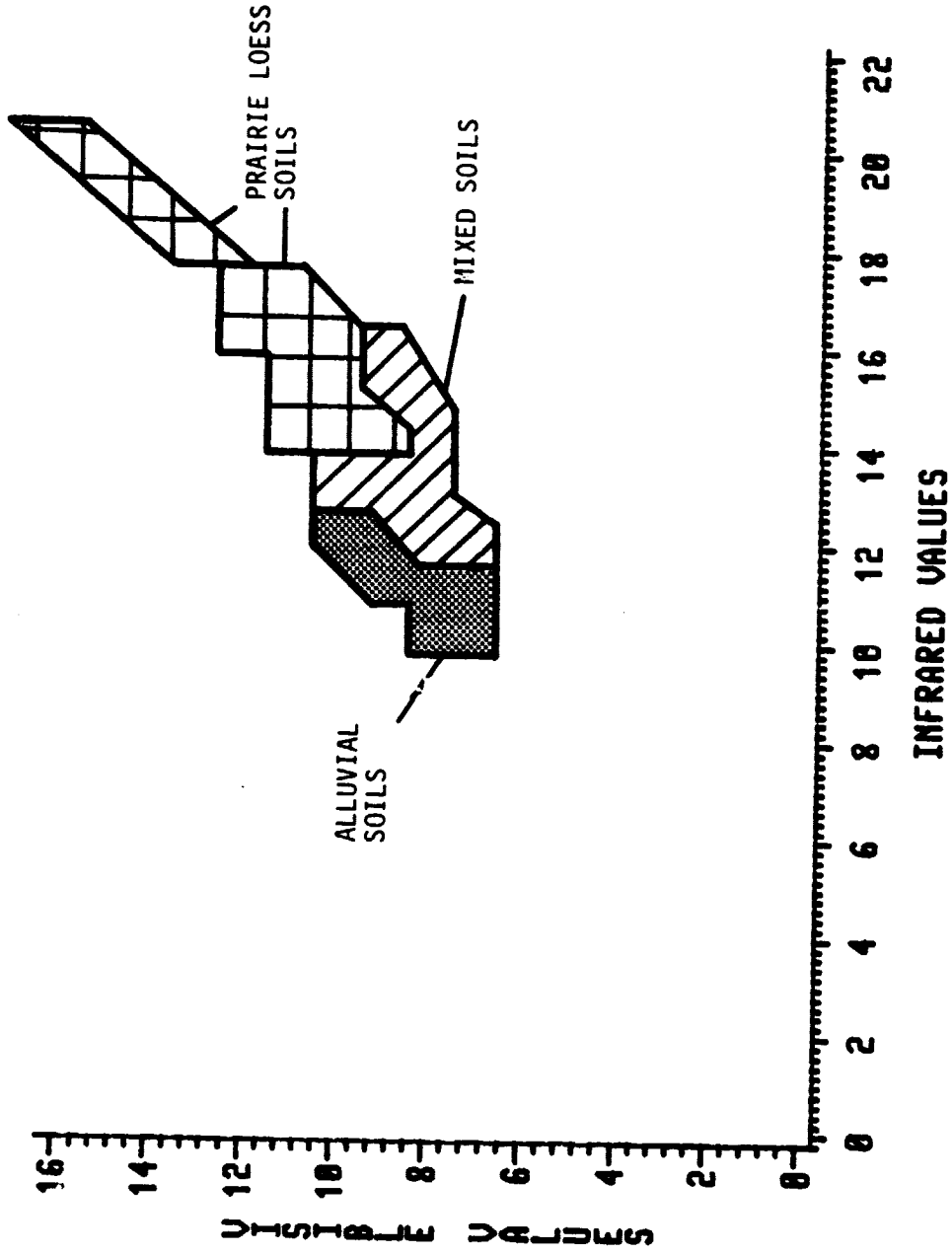
INFRARED VALUES

Figufe 2-9. Partitions of Soil Types.

2-14

both channels and the Prairie Loess soils the highest in one or both channels with few exceptions. The "mixed" soil cells generally include cells which already straddle both soil types such as is found in southeastern part of the scene or cells which include large percentages of deciduous trees. One anamalous cell displaying the highest values in both channels could not be reliably classified.

Other environmental conditions covary with changes in soil type. The combination of conditions led to the eight class scatterplot partition shown in Figure 2-10. Each partition is in some way uniqually different from all others. For example, average vegetative density tends to increase from cell type 1 to cell type 8. Along two lines - woody vegetation and herbaceous vegetation - a basic difference between woody and grass like vegetation occurs and as vegetation density increases in either class, spectral values change correspondingly. Soil color changes from dark to light covary with soil type changes from alluvium to Prairie Loess. Similarly, soil moisture and topography appear to vary in the same way. Thus, the basic physiographic division determined the most general partitioning. Environmental factors coverying with physiographic changes and forming a regional ecotone induced secondary divisions in the partitioning scheme.

The identical partitioning scheme was used to partition the 12 1/2 x 12 1/2 and the 25 x 25 mile cell scatterplots. The trends in the means and variances which were described above, were noted again in the scatterplots. In essence, the positions in the scatterplots containing the highest and the lowest mean values disappeared as resolution decreased. Similarly, the between cell variance decreased as evidenced by fewer and fewer partitioned classes (i.e. there were 8, 7 and 4 classes corresponding to each of the three resolution levels) in the study area. This trend is shown in Figure 2-11 which compares the classes which were partitioned, however, when related back to Table 2-2 seemed to be defined by the cell type description regardless of the constituent area. Spatially, the shape and boundary position tends to deteriorate as cell size increases, similar to previously noted spatial trends.

2.5 Effect of Increases in cell Size on Gray-McCrary Vegetative Index

The filtering affect of grid generalization as the GMI is similar in most respects to the characteristics of individual and combined channels. In the late May/early June scene, the bare soils induce a strong control on the spatial pattern. Figure 2-12 shows the filtering affect of grid generalization of cells between 6 1/4 by 6 1/4 to 50 by 50 mile cells. At 6 1/4 x 6 1/4 mile cells, the general physiographic pattrern emerged as a result of low GMI values characteristic of the alluvial soil and glacial till soil areas and the relatively higher GMI values associated with the Prairie Loess soils. Figure 2-13A illustrates the trend by showing both the negative and positive deviations from the scene-mean GMI value of 4.3. The other illustrations in both figures show the corresponding effects of grid generalization at 12 1/2 x 12 1/2, and 25 x 25 mile cell grids.
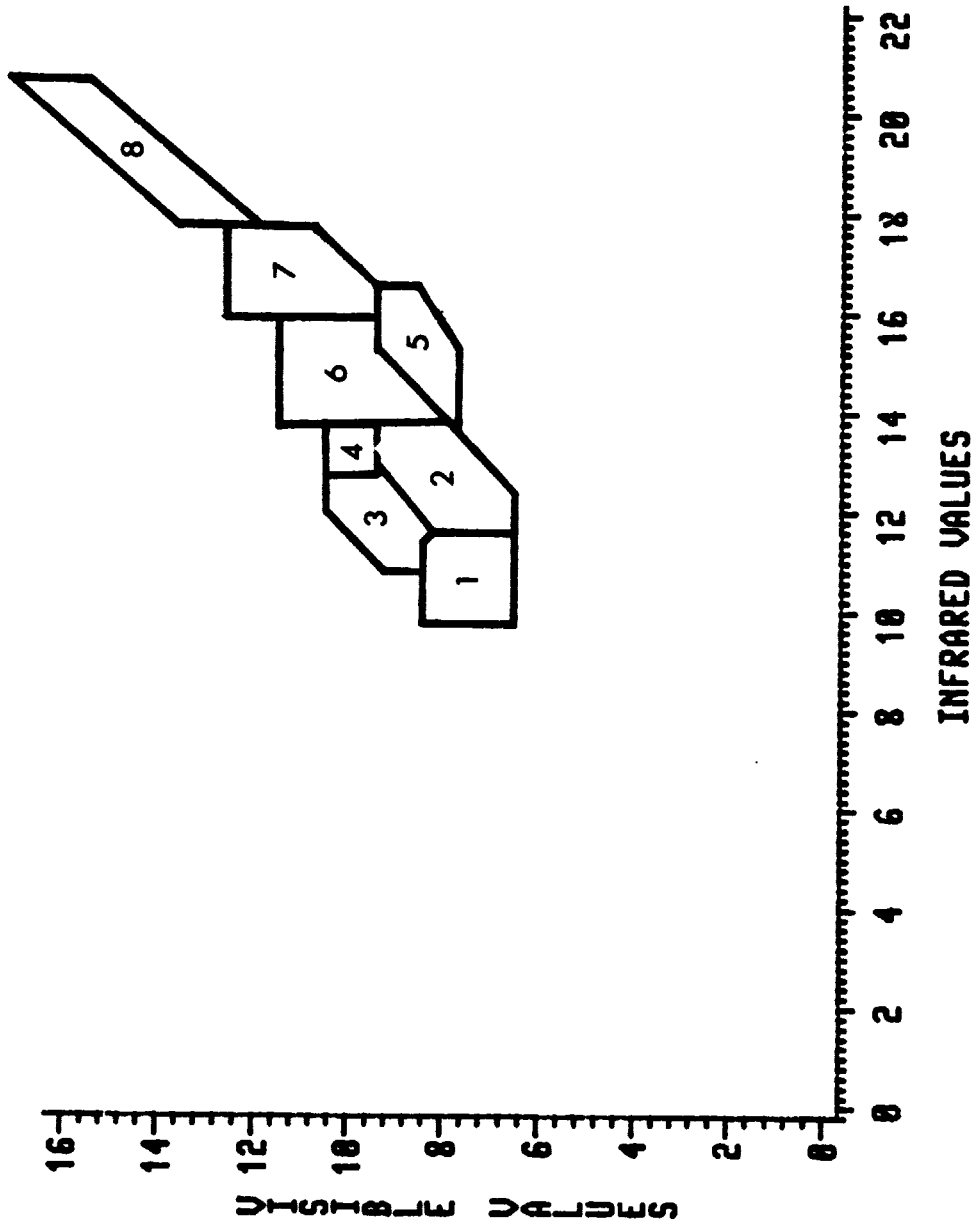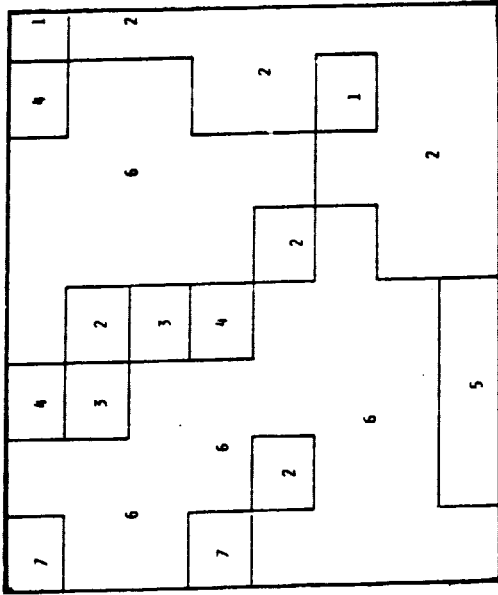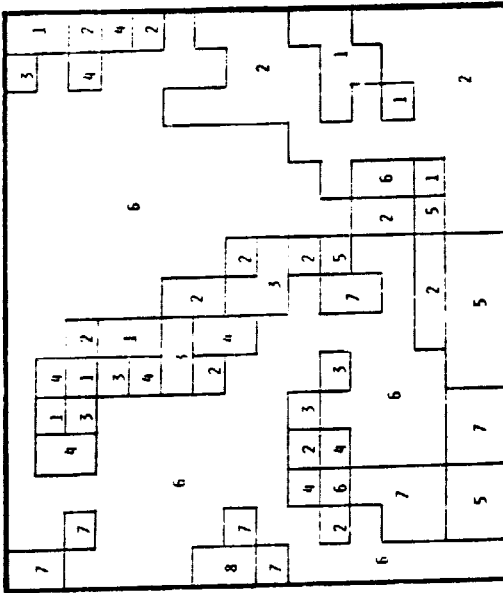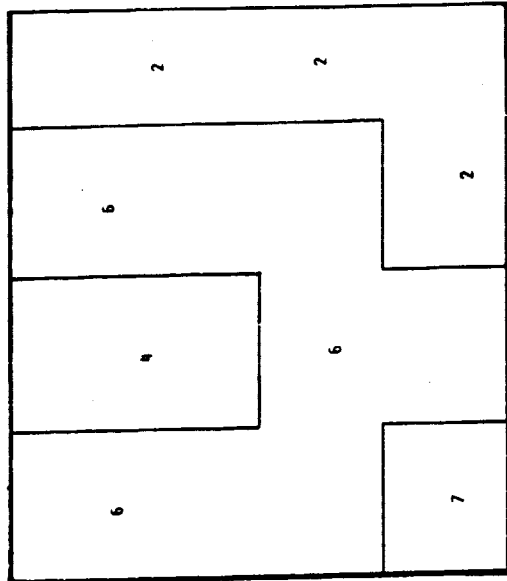
2-15

Figure 2-10. Partitions of 8 Cell Types.

B. 12 1/2 CELL SIZE

A. 6 1/4 CELL SIZE
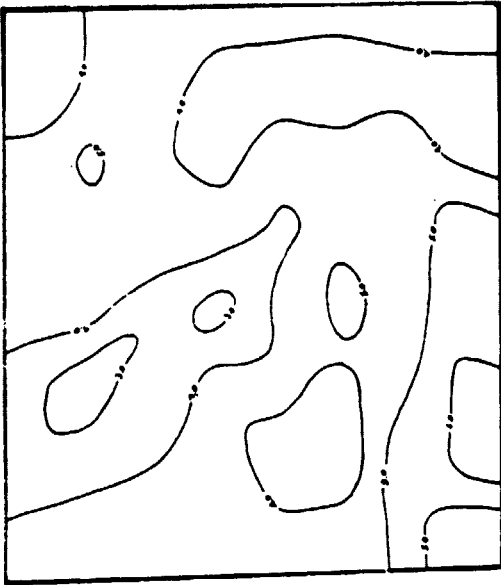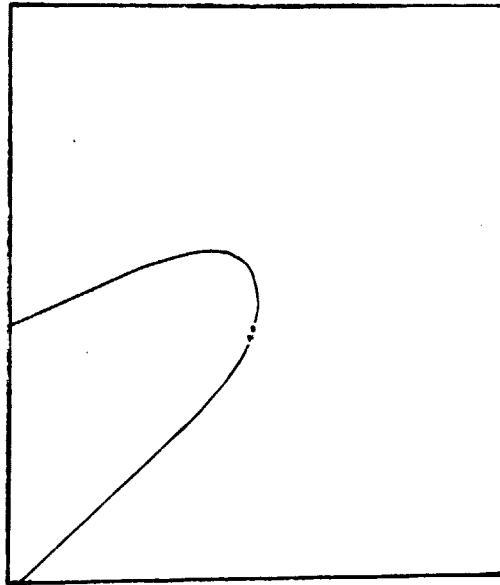
C. 25 CELL SIZE

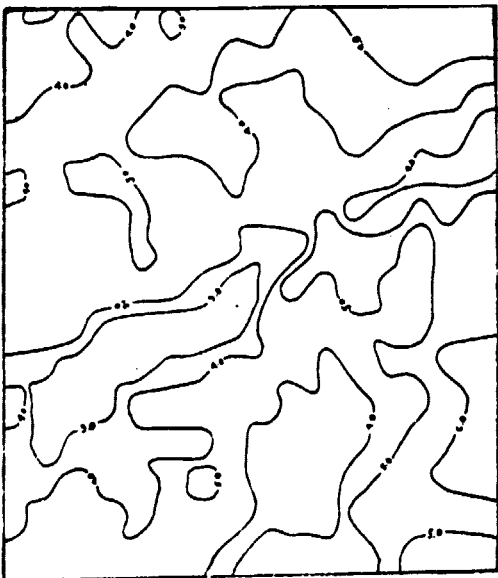Figure 2-11. Partitioned Class as a Function
of Decreasing Resolution

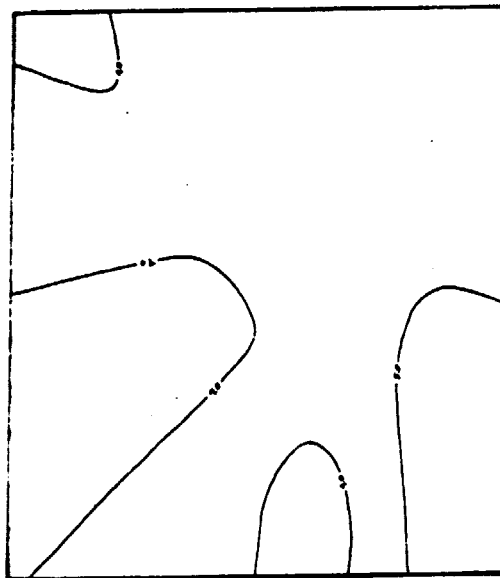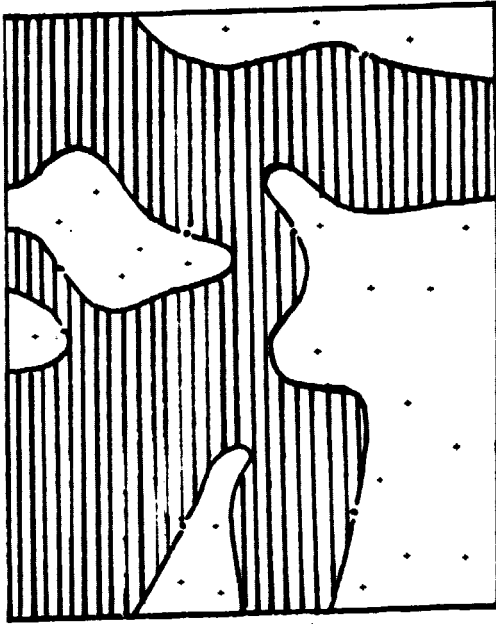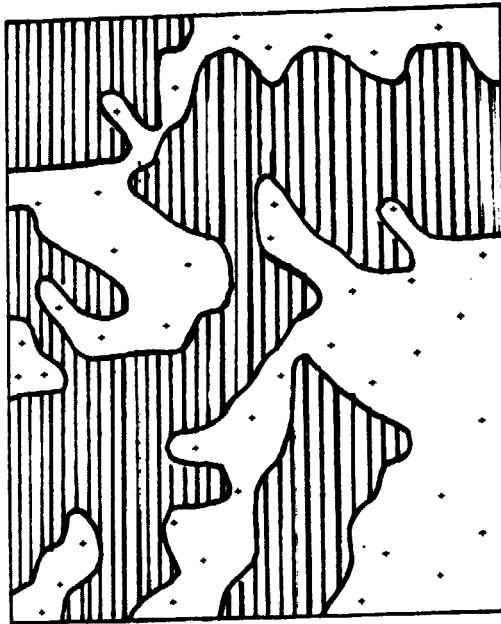Figure 2-12B.

Figure 2-12D.

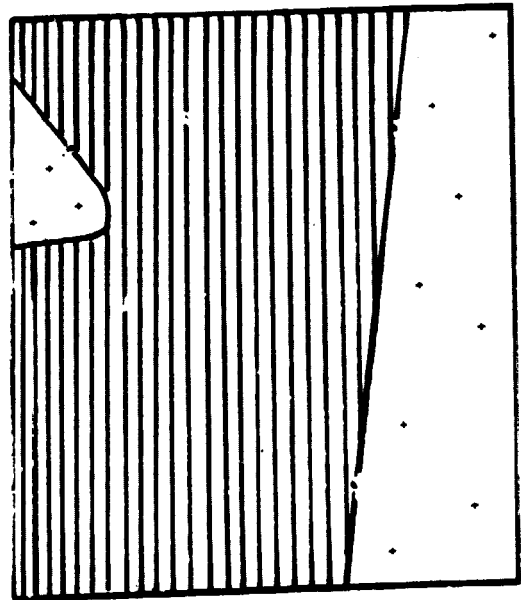Figure 2-12A.

Figure 2-12C.

Figure 2-12. Filtering Affect of Grid Generalization on the GMI.

B. 12 1/2 x 12 1/2 CELL SIZE

A. 6 1/4 x 6 1/4 CELL SIZE

C. 25 x 25 CELL SIZE

Figure 2-13.   Deviations of GMI from Overall
              Average GMI.

It is significant to note that the range in GMI values of Figure 2-12A
varies between less than 3.0 to greater than 6.0, and less than 4.0 to
greater than 5.0 in Figure 2-12C. The spatial pattern in 2-12C
roughly approximates a regional trend, however the range of values
differs by only one GMI value. It is not clear in interpreting the
pattern and values in 2-12C if the small difference in GMI values is
significant in terms of crop condition. Furthermore, the distribution
of the positive and negative deviations characteristic of the large
cells (Figure 2-13C) no longer depicts the physiographic controls as
do the smaller grid cells.

As is illustrated in previous sections, more and more variance in the
spectral characteristics - in this case the GMI parameter - is packed
into single values. Figure 2-14 shows the "packing" trend. The
columns in the table at the top of figure show an areal measurement
within contour increments. The rows show the changes in area within
increments as a function of cell size. The same information is
graphed below. The most obvious shift in GMI values is toward the
average increment of 4 to 5, thus the growth in that curve is roughly
a measure of error in GMI classification. Between 6 1/4 by 6 1/4 mile
cells and 25 x 25 mile cells, the 4 to 5 increment grows approximately
30 percent. That is, roughly 30 percent of the area which is labeled
with values ranging between 4 and 5 GMI units is actually some other
value.

It is left to the reader to determine if that magnitude of error is
usable in specific applications.

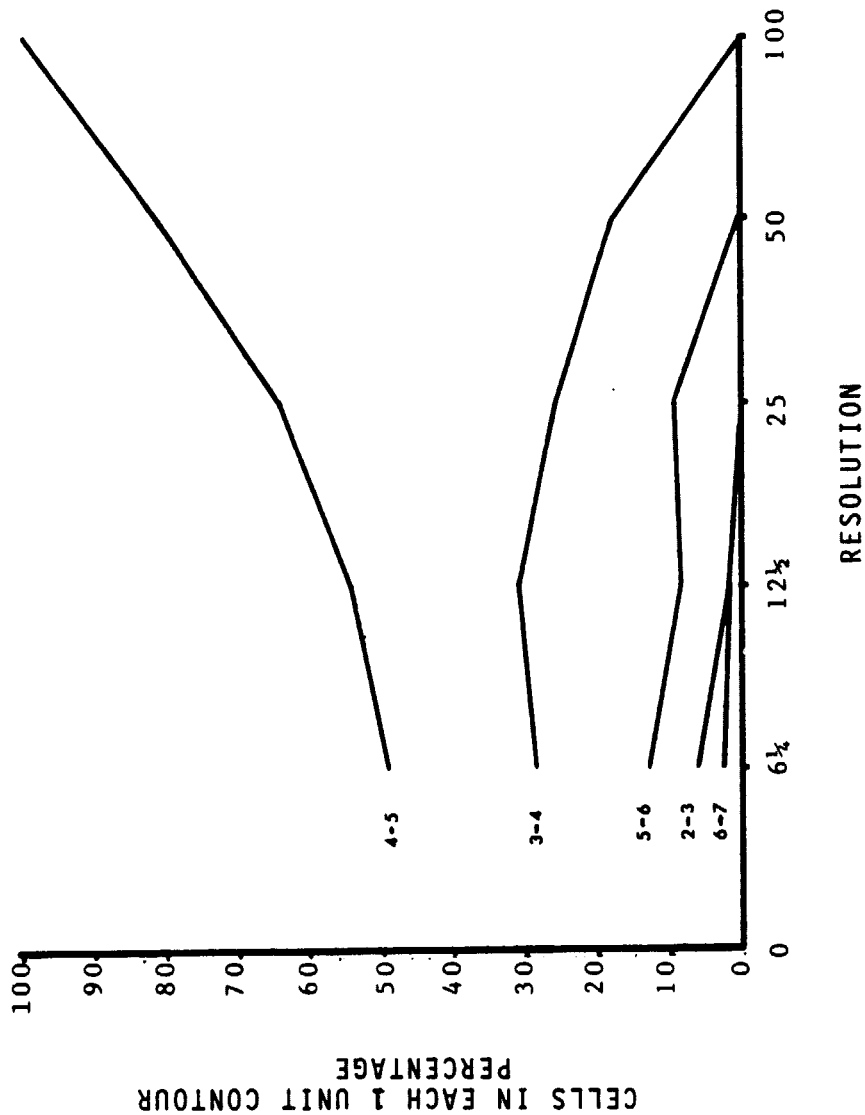| CELL SIZE INCREMENT	6½ x 6½ DOTS	%	12½ x 12½ DOTS	%	25 x 25 DOTS	%	50 x 50 DOTS	%	100 x 100 DOTS	%
2 - 3	49	6.3	16	2.1						
3 - 4	222	28.6	251	32.4	204	26.3				
4 - 5	382	49.2	426	54.9	501	64.6	138	17.8	776	100
5 - 6	100	12.9	67	8.6	71	9.5	638	82.2		
6 - 7	23	3.0	16	2.1						

Figure 2-14. Distribution of GMI Cell Values.

2-21

3.0 SUMMARY OF INFORMATION CONTENT CHANGES

Information contained in any pixel or cell may be reduced to five basic categories which apply to most geographic areas of the world where agriculture is performed. These categories include the following:

1. Cadastral information - particularly boundaries and positions of man-made features.

2. Vegetal information - generally physiognomic and possibly generic or in rare cases, species.

3. Soil (or rock) information - generally soil or rock types and associations, and associations with geomophology and vegetations.

4. Water information - particularly discriminated as a function of surface (and near surface) turbidity.

5. Physiographic boundary information - generally defined as a function of vegetation, soils, and water distributions.

Discrimination of any one of these categories in remote sensing is based on a single set of spectral parameters and is a function of the areal dominance of the category on the ground. A resolution cell correctly labeled "urban", "bare soil", "forest", or "wheat", etc., simply indicates the areal dominance of that class within the ground area subtended by the instantaneous-filed-of-view of the recording instrument. In a non-temporal data set research has shown that is is feasible to inductively determine subclasses such as "wheat" or "urban" primarily because of a priori knowledge of the area rather than because of specific spectral responses. Experience has also shown that combinations of one or more of the five basic categories of information can produce an averaged spectral response that resembles something other than that which is actually on the ground. Thus, the information content is altered as a function of both spectral and resolution factors. Using these assumptions the following analysis of information content in the study area was made.

3.1 Cadastral Information

In terms of ground features which are detectable at Landsat resolution, but not at Metsat resolutions, the primary loss appears to be in the cadastral information in the Pottawatomie Study Area. Whereas such features as urban areas, major highways and thoroughfares, large bridges and buildings, most field patterns are discernible on the Landsat image, they blend generally with ambient environments on the Metsat image and at the 6 1/4 by 6 1/4 mile level, are obviously not detectable.

Examination of the spectral signature of the cadastral information indicates that most man made features (i.e. building, roads, cities, canals, irrigation systems, etc.) fall at either the high end or low end of both the visible and infrared channel histograms. The bell

shaped curve, such as the infrared channel displays, leads one to conclude that; 1) most of the cadastral information is on the perifery or in the "tails" of the spectral image and does not contribute in a major way to the variation in the mean scene signature, and 2) is spatially not important in this study area.

Thus, as resolution progresively decreases, cadastral information "disappears" rapidly. Even at Metsat resolutions, when compared with Landsat, the cadastral data is highly degraded, severely limiting recognition and possibly even detection. In terms of crop condition assessment, the loss of this "noise" may be desirable, enabling an analyst to better recognize regional trends. Beyond Metsat pixel resolutions, it is no longer feasible to extract significant cadastral information, nor do cadastral features significantly alter cell means throughout the study area.

An important trend to note, however, is the "loss" of the "tails" in the histogram as resolution cell size increases. This trend is seen in each of the five basic categories and is repeated with each decrease in resolution. This point and its significance is discussed in detail below

3.2 Vegetal Information

The grid generalization of vegetation from Landsat resolutions to Metsat resolutions or less is away from species or generic recognition, toward recognition of major physiognomic units initially and general "green" vegetation finally. At Metsat resolutions major forested areas are clearly discernible from areas dominated by herbaceous type vegetation cover including agricultural crops. At 6 1/4 x 6 1/4 mile cell resolutions, the dominance of forest cover occuring in a cell still induces spectral and spatial discrimination. At lower levels, the occurrence of forest induces a sufficient spectral effect often enabling discrimination. Beyond 12 1/2 x 12 1/2 miles resolutions, however, it becomes difficult to inductively reason any more than the possible occurrence of forest in a cell which is mixed.

Typically, cells containing forest features at any resolution are characterized by mean signatures which are lower in value relative to herbaceous dominant cells. However, a great difference is seen in the within cell variance which typically greatly exceeds that of the herbaceous dominant cell thus aiding discrimination, even at the lowest resolution levels.

Separations of herbaceous vegetation beyond Landsat resolutions is generally not reliable and beyond the 6 1/4 by 6 1/4 mile cell, not feasible in the study area examined. Herbaceous vegetation appeared to have spectrally similar means and variances and clustered in a large single class. Some separation appeared feasible as a result of associations with particular soils. The reader should again note that most of the study area at this early time of the growing season was

characterized as having a relatively low percentage of herbaceous type vegetation cover. At later stages in the growing season, the above conclusion could feasibly be altered.

3.3 Soil Information

The majority of the cells at all resoution levels were "soil dominant" in character. That is to say, the soil sensed in the area subtended by the instanteous-field-of-view of the sensor contained a greater percentage of bare soil than any other of the five basic information categories. Thus, the spatial trend in soils was apparent down to the lowest resolution levels of 25 by 25 mile cells.

The mean value of alluvial and glacial till soils was lower than the Prairie Loess soils and the within cell variance of the former higher than the latter. Regional soil partitions therefore discriminated well at all levels, with the greatest detail obviously apparent at the highest resoltuion.

At Landsat resolutions, bare-soil fields often contrasted with ambient vegetation, roads, etc., thereby providing good discrimination of field boundaries. At Metsat resolutions, such discrimination largely disappeared, and by 6 1/4 by 6 1/4 mile cells or larger agricultural field boundaries were totally integrated with ambient conditons.

3.4 Water Information

Only a poor representation of water dominant pixels were available for examination in the study area. At resolutions levels greater than Metsat, the water pixels within the cell negligably affected the average signal and appeared to have a slight affect on the variance. Because of the small percentage of such pixels in the scene, the effect became increasingly negligable with increasing cell size. It is feasible to speculate that large percentages of water in a cell would have significant effects on estimating crop conditons.

3.5 Physiographic Information

The largest physiographic feature contained in the study area is the alluvial valley of the Missouri River and several of its tributaries, particularly the South Platte River Valley. The basic shape and area of the Missour River Valley is retained for the 12 1/2 x 12 1/2 mile cell size level of resolution. Beyone that level, the alluvial valley is detected but is not recognizable as a unique geographic feature. Smaller tributaries are integrated with ambient features at higher resolutions and the greatest detail in physiographic boundaries is realized at the highest resolutions. Interestingly, at the 6 1/4 x 6 1/4 mile cell level, an accurate conception of the river system is obtained when the digital data are transformed by contouring to an analog form. At each level of resolution beyond Metsat resolution, in fact, better areal expression of the general physiography is attained by contouring the original digital data.

During the late spring/early summer part of the growing season, the
basic categories of information combine to discriminate the major
physiographic units. In addition, it is known that the vegetation,
the soil type, and the water occurrence convey as a function of
changes in physiography. For example, soil color is darker in the
alluvial valleys and the glacial till areas than in the Prairie Loess
areas. The darker soils in the scene are almost always associated
with topographically low areas and/or soils with a higher percentage
of soil moisture. Forested areas similarly are associated with
alluvial valleys, but primarily with the steepest slopes on the fringe
of the valley.

The basic information constituent of cells combine to spectrally
define the cell, but are not completely independent of each other.
Thus knowledge of one the variations in one feature provides
information by association on other types of feature variation on the
ground.

APPENDIX A

APPENDIX A

STUDY AREA DESCRIPTION

Location and Size

The study area referred to as the Pottawatomie Study Site is situated in western Iowa and eastern Nebraska. The site was selected to correspond closely to Landsat Scene E-2504-16211, acquired 09 June, 1973. Thus the study area measures approximately 100 nautical miles by 100 nautical miles. All Metsat data and ancillary data closely correspond to this Landsat scene.

Ground Truth

The only available ground truth for this study is in Pattowatomie County, Iowa, LACIE sample segment number 886 sigutated near Oakland, Iowa (95° 20' 24" west longitude, 41° 10' 48" north latitude). Data included in the segment packet consists of aerial photography, labeled ground truth overlays, meteorological data, soils data and several Landsat, false color images with corresponding overlays. The five by six nautical mile segment is representative of the southeastern portion of the study area in terms of soils and physiography. It represents only 1/300 of the total area under study.

Ground truth type information for the remaining 99.7 percent of the study area was derived from general regional sources of information which include USGS, topographic maps, soil maps, Landsat composite imagery, and soils and agricultural documents. Information derived from these sources and used in this study pertain to the study area shown in Figure A-1 (Study Area Scene).

Regional Physiography

The Missouri River alluvial valley bisects the scene, approximately into western and eastern parts and also forms the political boundary between Nebraska and Iowa, respectively. On the Landsat imagery and the topographic maps, the Missouri river alluvial valley is the predominant geomorphic feature in the scene. Extending the full 100 mile length of scene from the northwestern corner to the southeastern corner, the valley varies from four to 20 miles wide. The river itself and many abandoned channels are clearly detected on the Landsat data as they meander toward the southeast.

Entering the valley from the west, the Platte River bends southward then westward where it reaches the Missouri just south of the city of Omaha. The Platte River alluvial valley ranges from less than one mile to more than 8 miles in width and is considered an important physiographic element in the scene.

Figure A-1. Pattawatomie Study Area (Reproduced from ONC F-17).

Several other rivers individually contribute to the alluvial physiography in the scene in a secondary way, but have a significant cumulative spectral effect. These include the Elkhorn River which is tributary to the Platte, and the West Nishnaboin River Basin, the Boyer River Basin, the Little Sioux River Basin, and numerous additional smaller rivers which flow south-southwest to reach the east bank of the Missouri River. With the exception of the southeastern quadrant of the scene the study area is characterized by gently sloping terrain. Regional slopes toward the south-southeast deviate and increase locally, and sharply only along the ridges of the alluvial valleys. In the southeastern quadrant, slopes tend to increase (i.e. up to 18 percent) when compared with the rest of the scene (0-10 percent). Numerous small creeks and rivers which cut the terrain in a dense dendritic pattern result in a locally undulating ridge and swale topography.

A small corner of the northeastern part of the scene catches the highland divide between the Missouri River Drainage Basin and the Des Moines River Basin to the east. Drainage in this corner of the scene flows southeast toward the Des Moines River.

Soils

Approximately 65 percent of the soils in the scene fall into a general group of Prairie Loess soils. Typically, Prairie Loess soils are light colored, fine grained soils located on topographically high, gently sloping to flat terrain. A small percentage of the Prairie Loess soils are found on the upper levels of the steep sloped alluvial valley ridges.

The remaining 35 percent of the scene consists mainly of the alluvial soils, associated with the drainage network and soils derived from glacial till. In contrast with the Prairie Loess soils, the alluvial and till soils are typically associated with the topographically low elevations, are relatively dark in color and range in grain size from fine silt to medium sands. In most areas on Landsat images these soils are clearly defined in contrast with the lighter colored Prairie Loess soils, however in the densly disected southeastern quadrant, the alluvial and till soils of the small creeks and rivers blend imperceptibly with the Prairie Loess soils and the vegetation canopy. As is shown in the section below, however, there is a regional spectral effect which is sensed and contributes to easy documentation of soil groups.

Vegetation Canopy and Agriculture Cropping

In the late May, early June time period during which the study data was conducted, approximately 30 percent of the study area is covered with vegetation (undifferentiated). The greatest density of vegetation occurs along the alluvial valley ridges which support natural, deciduous, Hickory-Oak forest. An estimated 10 percent of the study area consists of forest and shrubs, while the remaining 90 percent is almost entirely agricultural. The lowest density of vegetation appears in the agricultural fields, recently plowed and planted with corn or soybeans and particularly in the broad alluvial valley of the Missouri River. Distributed, rather uniformly over the Prairie Loess soils and consisting of about 20 percent of the scene are unimproved pasture of native shrubs and grasses;

improved pasture of immature stands of alfalfa, clover, and oats; and a small percentage of ornamental shrubs and trees.

The major agricultural crops of the farm lands in the study area are corn (50 to 60 percent) and soybeans (30 to 35 percent). Planting of both crops is completed by mid-May, but on the late May early June Landsat imagery both corn and soybean fields are so immature that they appear as "bare soil." About 5 to 10 percent of the farm lands are planted in oats, alfalfa, and clover which are seeded and/or partially developed, thus inducing a small cumulative effect on the spectral data. Although point-to-point correlations were not feasible, fields of oats, alfalfa and clover are apparently detectable at this time in the crop calendar.

1980 Plant Growth

Rainfall and temperatures affecting plant growth in the early part of 1980 were both initially below the norm. By April temperatures had reached and exceeded the norm, but precipitation remained low. In mid-May, heavy rainfalls had increased soil moistures so that by the end of May, nearly all stations reported adequate to surplus soil moisture levels. Thus, adequate rainfall and an above normal departure in growing degree days by the end of May created good growing conditions for both native vegetation and agricultural crops. These conditions tended to remain good through the growing season with above average yields for most crops.

Urban Areas

The only major urban area within the study area is Omaha, Nebraska, located in the south central part of the scene. An urban area of this size was easily detectable at both the Landsat and Metsat resolutions. Many of the smaller towns and villages within the study area shown on the Map in Figure A-1 were clearly detectable on the Landsat data, but not on the Metsat data.

Summary

The regional distribution of soils and vegetation in the scene and the stage of growth of the latter, jointly affect the spectral response detected and the spatial depiction on remotely sensed data. Table 1-2 provides a general summary of estimates of the percentage of soils and vegetation in the study area; the stage of growth in vegetation, and the general distribution throughout the scene.

★ U.S. GOVERNMENT PRINTING OFFICE 1983—660-013/2483