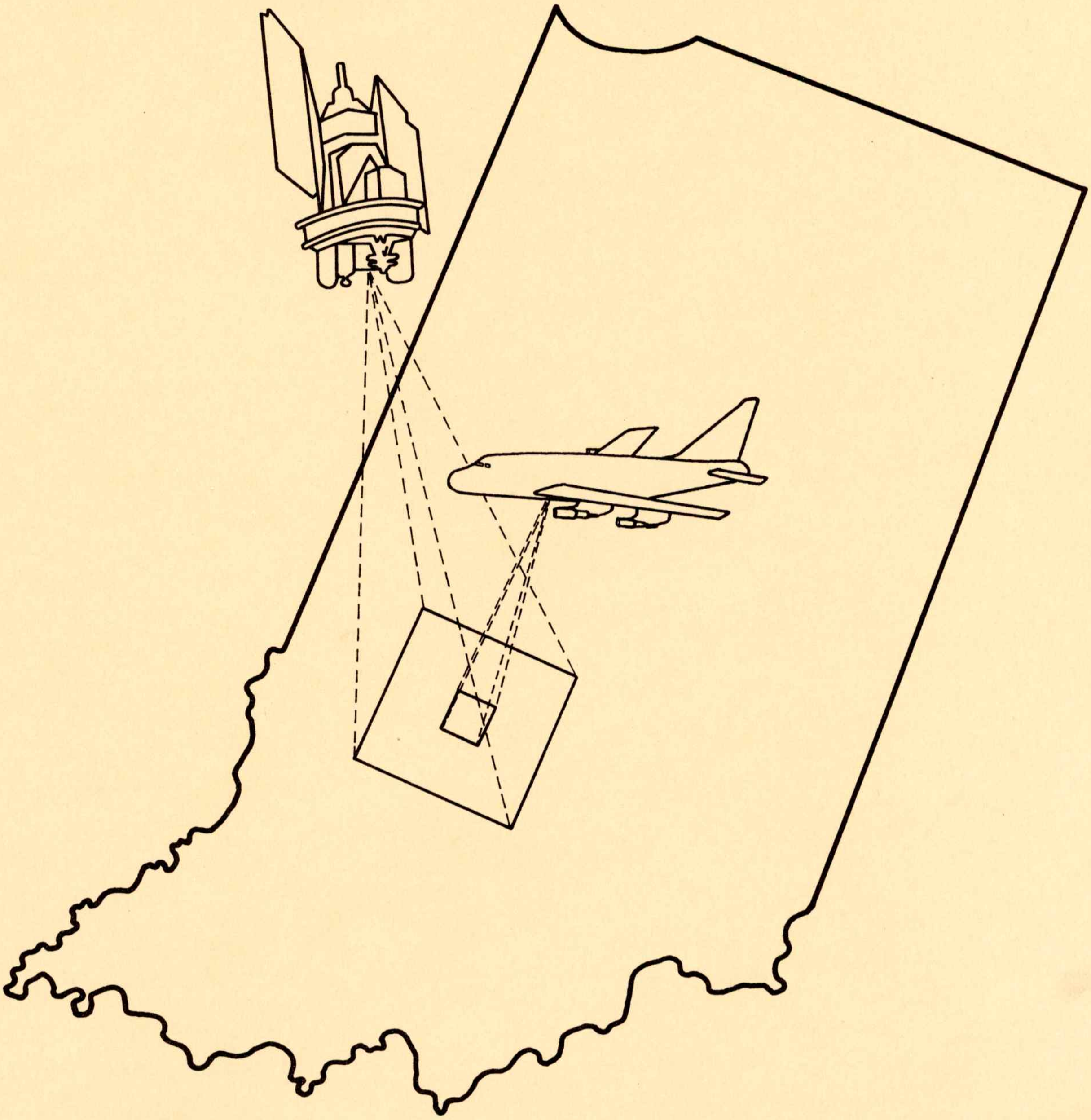
LARS Contract Report 070578

Semi-Annual Status Report

Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana



Laboratory for Applications of Remote Sensing
Purdue University W. Lafayette, Indiana
December 1, 1977 - May 31, 1978 NGL 15-005-186

LARS Contract Report 070578

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Semi-Annual Status Report

Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana

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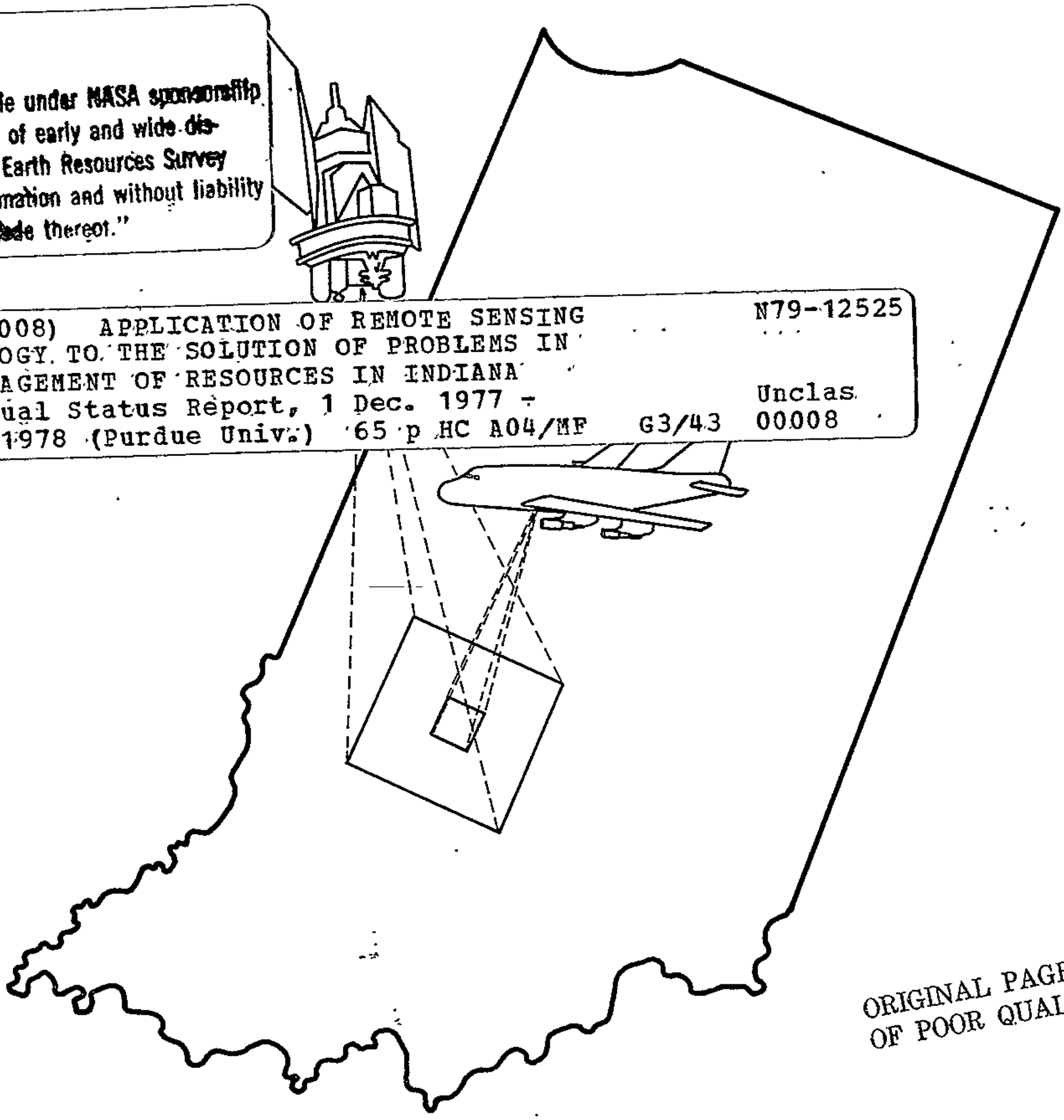

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INTRODUCTION

This semi-annual status report covers the period from December 1, 1977 to May 31, 1978 and contains a review of the research and applications, completed or in progress, as funded by the Office of University Affairs, NASA and conducted by Purdue University, Laboratory for Applications of Remote Sensing.

This reporting period marks the second half of the fifth year of funding for a proposal entitled "The Applications of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana." As indicated in this title, the purpose of this work is to introduce remote sensing into the user community within the state of Indiana. The user community includes those local, regional and state agencies involved in the decision monitoring and/or managing processes of the state's resources.

In order to carry out this work it is not only necessary to initiate projects with these agencies but also it is necessary to meet with and provide information to as many people and groups as well as agencies as possible. During the past six months numerous meetings were held with many different groups.

Among the groups that were contacted and received information about this program were:

Area Planning Commission, Tippecanoe County
Indiana Geological Survey
U.S. Forest Service
Tipton County Commissioners and Engineers
Indiana Department of Natural Resources

  a) Division of Reclamation
  b) Division of Forestry
  c) Division of Properties, Fish and Wildlife
  d) Soil and Water Conservation Committee

Soil Conservation Service.

Listed below are the projects that are reported in this document:

Soils Inventory
Forestry Demonstration Project
Heat Loss Determination in Residential Buildings.

SOIL INVENTORY PROJECT

INTRODUCTION

The acceleration of the National Soil Survey Program and the production of useful, high quality soil surveys in Indiana are among the prime goals of the USDA/Soil Conservation Service and the Indiana Department of Natural Resources Soil and Water Conservation Committee. The wide use of soil surveys for engineering and planning purposes in addition to agricultural uses has resulted in many specific questions concerning the physical nature of the different soil units depicted on soil maps. In order to provide the details necessary to understand the landscape composition and to provide interpretation of soil maps for specific uses, information of a quantitative nature is needed. To accomplish this task all avenues are being considered, including remote sensing technology which can provide quantitative measurements through computer analysis of Landsat multispectral scanner (MSS) data.

OBJECTIVE

The overall objective of this task is to determine the applicability of using computer analysis of Landsat multispectral scanner data in accelerating and improving the quality of the soil survey program in Indiana.

To evaluate the usefulness of the data the following specific studies were initiated:

1. Evaluation of the usefulness of spectral soil maps produced from multispectral scanner data using pattern recognition techniques as quality control in soil surveys and as a means to evaluate quantitatively the soil mapping unit composition.
2. Investigation of the possibility of producing high quality general soil maps using false color Landsat imagery as the base map.
3. Development of a soil parent material map using multispectral resource data.
4. Determination of the feasibility of producing a spectral soil map on a county-wide basis with its accompanying manuscript and evaluation of the utility of this type of soil survey report to user groups.
5. Evaluation of the usefulness of superimposing computer classification results upon aerial photobase maps in order to gain the benefit of the landscape perspective.

METHODS AND MATERIALS

Remotely Sensed Data

The remotely sensed data were of two forms, i.e., aerial photography and Landsat data. May 1976 aerial coverage of Jasper County, Indiana was taken at an altitude of 2000 m creating an approximate map scale of 1:15840. The Landsat data were collected June 9, 1973 and were relatively

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free of vegetative canopy, snow cover, interfering clouds and fog, and scanner distortions.

Data Analysis

Base Map. A base map consisting of a block of 85 black and white panchromatic aerial photographs (scale 1:15,840) was used in the registration of the Jasper County Landsat data. Known north-south roads were located on the aerial photography and used to parallel a y coordinate axis. A three-parameter linear transformation was used to block the photos to a common coordinate system.

Halftone acetate positives were created from the photographs. The resulting transparencies were rectified and trimmed to field sheet size. Rectifying corrected for tilt and vertical aspect, which improved scale variations and crabbing (rotation). The halftone acetate positives were used for comparing field soil patterns with the spectral classification of soils.

Geometric Registration and Rectification. The blocked set of aerial photographs was used as a base in the geometric registration and rectification of the Landsat data. Corresponding points between the two images (Landsat and photo block) were located by either displaying the Landsat image on a CRT screen or by cluster analysis of the digital data. Groups of approximately 100 data points were clustered and specific points within the clustered areas were located on the aerial photos. A twelve parameter equation was used to transform the coordinates between the images.

Compatible scales between the base map and the Landsat data were accomplished by expanding the Landsat data to a scale of 1:15840, the mapping scale for Jasper County. For this registration a cubic convolution resampling algorithm was used to rescale the Landsat image to 1:15,840. Intermediate data values were calculated using a Lagragian third order equation that used a 4 x 4 matrix or 16 spectral points. On the curve of this equation intermediate data values were plotted and used in expanding the scale. This method had the effect of smoothing the image which could contribute to a somewhat less accurate classification but provide a higher quality map image for soil mapping. Classes that are very close spectrally could lose their distinctness because of these calculated intermediate values.

Compilation of Color Map Image. Three channels (1, 2 and 4) were combined to create a false color composite map, generally referred to as a false color image, at a scale of 1:180,000. This image was generated to aid in stratification of the county spectra. Enlarging the image to 1:120,000 enabled the user to delineate or interpret finer detail.

Stratification of the County

Geologic History. The geology of Jasper County is quite complex. Underlying the county are tertiary and quarternary bedrock valleys formed primarily by water erosion. These valleys, initially filled by quarternary debris, were later covered by the early Kansan and Illinoian glacial deposits.

Evidence of much earlier geologic phenomena occur to the west where coral reef domes reach within one to two meters of the surface. The reefs are thought to be a product of the Silurean or Devonian ages and are a good source of limestone. Material that accumulated to the side of the domes, most likely water deposited, is generally not of good quality which is why the smaller domes have been largely left untouched by limestone excavation.

Glacial deposits that covered all of Jasper County from the Kansan and Illinoian were obliterated by a coalesced ice sheet from the Lake Michigan and Erie glaciers of the early Wisconsin age. A thin ice extending from the Saginaw northeastern lobe covered the previous glacial activity and appears to have truncated the Marseilles moraine in the eastern portions of the county resulting in belts of kettles and intervening dunes covered by submorainic rises. Characterized by the thin ice sheet the Saginaw lobe covered low lying areas, but largely left higher elevations untouched. Present surficial deposits in the lower areas are credited to this glacier. The retreating glacier also left melt water laden with silts and clays which, when the water eventually subsided, left these lacustrine deposits.

Outwash sands were blown into parabolic and longitudinal dunes across the northern part of the county. Located under these dunes are peat areas that suggest vegetation once grew in ice block depressions left by the glaciers before being covered by (aeolean) sands. Vegetation establishing itself on the dunes gradually caused them to stabilize. After glacial activity subsided, geologic changes within the county have been in the form of drafting outwash sands and the accumulation of peat and marl in low lying areas.

This complex geology was considered in the compilation of a parent materials map of Jasper County. With the aid of Landsat data the area was investigated and parent material boundaries were delineated.

Stratification of Parent Materials. Training statistics are created by sampling data points and calculating mean and covariance matrix for each unique spectral range. This set of means and covariances was used to "train" a classifier by providing a data base for calculating probabilities of remaining data points belonging to certain distributions.

Prior work in Indiana revealed uniqueness of spectral classes to be lost as training statistics were combined over a large area such as a county. As spectral classes were combined, distributions became larger and closer together. To avoid this problem, in Jasper County, a parent material map was created so that training statistics could be generated and used in specific parent materials, thus eliminating the need to extend training statistics over broad areas. Parent material delineations also provided a means of separating spectrally similar but genetically different soil classes within Jasper County.

Image interpretation of the false color composite map, single band gray scale images, county and township road maps and knowledge of the geological history of the area were used to create the parent materials map of Jasper County. Initially, spectral stratification was noted on the image and investigated through field observations. The soil profile was sampled to determine underlying parent materials and characterize the profile. Munsell color charts were used to identify color boundaries for Alfisols, Mollisols and drainage characteristics. Textural boundaries were made and refined as the investigation progressed.

The completed parent materials map is shown in Figure 1. These boundaries were digitized and overlaid onto the Landsat data. By assigning unique values to the spectral data in a parent material and recording that data in a channel, that information could be used to discriminate statistical distributions created in each parent material. For classification four channels of Landsat data rescaled to 1:15,840 by a cubic convolution interpolation and precision registered to the 85 aerial photographs were used.

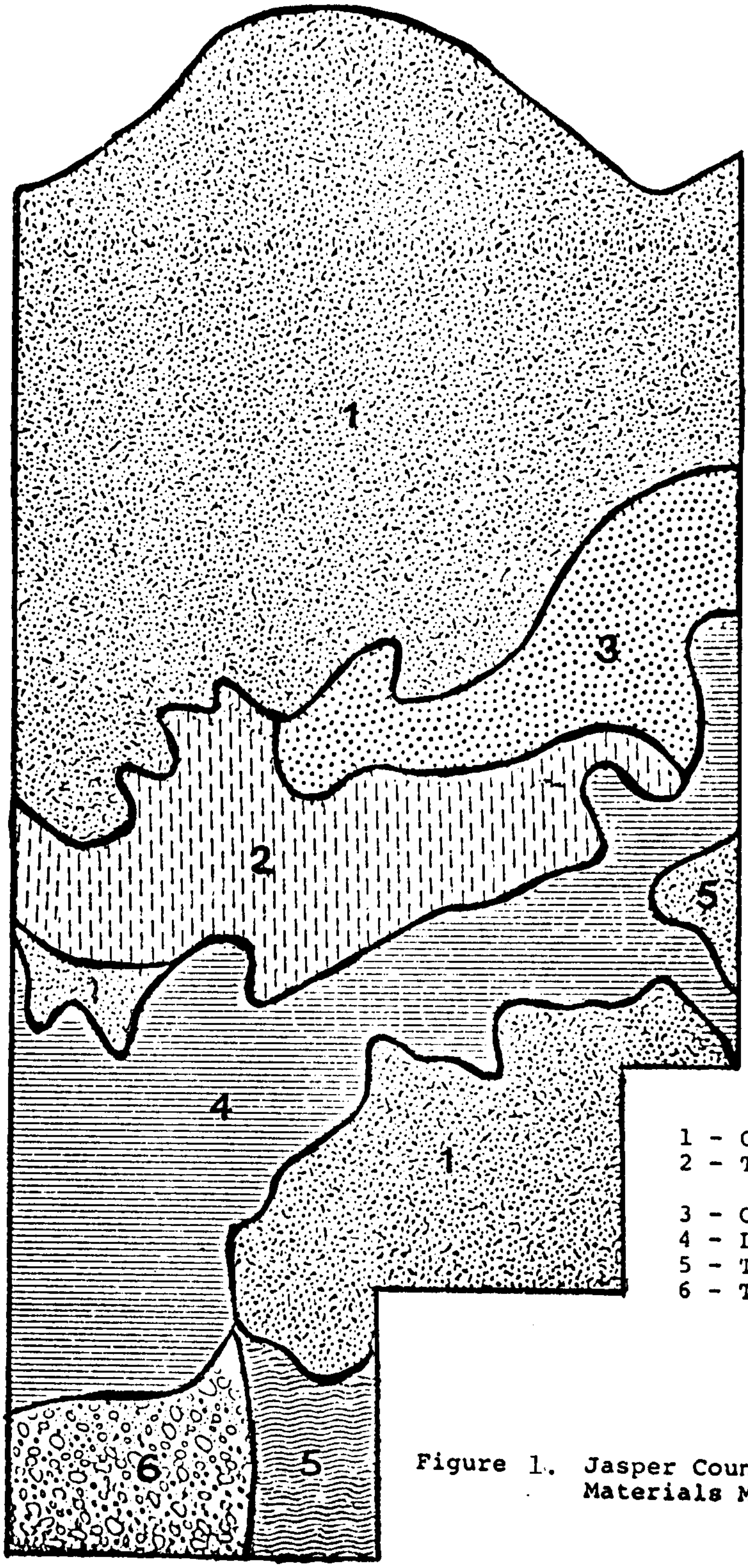
Digital Analysis of Remotely Sensed Data

Data Sampling and Analysis Techniques. Differentiating parent material boundaries made it possible to develop unique statistical distributions of the data within each delineation. Unique and subtle differences were hypothesized to be more distinct in parent material delineations than distributions developed across a whole county. Based on this hypothesis and the need to develop a better point sampling method, four techniques were devised. These techniques were designed to test the significance of parent material delineations within a statistical classification and to determine if differing sample point selections would change classification accuracies. A summary of these techniques is listed in Figure 2.

Two methods of sampling data points were used to determine which would most represent responses within the specified classification area. Subjective sampling of blocks of data was compared to systematically sampling points at specific line and column coordinates across the entire classification area. It was hypothesized that systematic sampling would more adequately represent the spectral variability of a scene rather than subjective sampling.

Another variability within the design was to limit the size of area classified. The importance of parent material delineations was tested by classifying only within parent materials as opposed to classifying the entire county without regard to delineated boundaries.

A method was devised to evaluate the final spectral classes as to countywide performance and accuracy within specific parent materials. Compilation of soils at selected locations was hypothesized to be an adequate means of testing performance. Due to time limitations the number of test sites was limited. Quarter sections within the county were selected as test sites because they were easy to locate and randomly selected. Quarter sections were numbered across the southern part of the county within each of three major parent material areas (outwash, lacustrine, till). Numbers were then randomly selected within each parent material area and corresponding quarter sections were noted on a Jasper County sections map. The 72-hectare quarter sections were then located on aerial photographs which were reproduced at 3 cm to 1 km to allow for mapping detail not generally mapped.



1 - Outwash
2 - Till-Rolling Moraine
3 - Outwash over till
4 - Lacustrine
5 - Till-Alfisols
6 - Till-Mollisols

Figure 1. Jasper County Parent Materials Map

	Data Point Selection	Clustering	Classification
Classification one	Subjective sampling of representative blocks of data within each parent material	Each block of data clustered requesting 13 cluster classes	18 spectral distributions used to train the Gaussian maximum likelihood classifier
Classification two	Systematic selection of data points from across the entire county (every eleventh line and column)	Clustering the entire county selecting data points every eleventh line and column. 18 cluster classes requested	18 spectral distributions used to train the Gaussian maximum likelihood classifier
Classification three	Subjective sampling used in classification one	Same cluster grouping used but groupings within parent materials kept as unique	Layered tree design used with Gaussian maximum likelihood classifier (60 classes)
Classification four	Systematic selection of data points of every fifth line and column within parent materials	Clustering within each parent material every fifth line and column. 13 classes requested per cluster	Layered tree design used with Gaussian maximum likelihood classifier (60 classes)

Figure 2. Data Point Selections and Subsequent Classifications.

General Analysis Procedure. A general procedure was followed for each of the four analysis techniques. Initially, a clustering algorithm was used that established a group of spectral classes consisting of means and covariance matrices which through an interpretive process was used in statistically classifying the county. Figure 3 shows the process involved in creating training statistics for the area.

Association of Cluster Classes to Specific Cover Types.

Plotting Mean Response Values. Classes derived from clustering were evaluated as to their spectral properties. Identification of broad categories of vegetation, soil and water could be made by observing the mean relative responses across the four channels (Figure 4). Characteristic curves of soil, water and vegetation make them easily identifiable.

Ratioing. Differences between vegetation and soil can also be detected by summing reflectances in the visible bands (.5-.6 μm and .6-.7 μm) and dividing by the sum of the two near infrared bands (.7-.8 μm and .8-1.1 μm). A high response in channel three and low response in channel two yield a ratio between channels of less than one that would indicate a vegetation response. Water is more responsive in the visible bands and therefore maintains ratio values over one. Response curves associated with soils generally follow an even pattern which displays values of one or more.

Magnitude of Response. When soils curves are identified, further separations between the soils can also be made by consideration of their relative magnitude. The relative response across all four channels is summed and these magnitudes are compared in order to identify such soils as a high spectral response of a well drained soil or low responding poorly drained soil. Drainage classes and their differing responses are shown in Figure 4.

Refinement of Cluster Classes.

Merging Function. Clustering statistics developed from more than one clustering can be combined into a set of calculated means and covariances. A merging function takes all statistical classes requested and compiles classes with new calculated means and covariance matrices. Combined classes were measured for divergence and pairs of classes with low divergence values were merged into one spectral group. The processor used to merge classes together calculated a new mean of all points contained in the original classes merged and a resulting covariance matrix.

Some classes were encountered that had a spectral response representative of both soil and vegetation (Figure 4). These classes were combined with a vegetation if they were spectrally similar or left to represent a soil if the influence of vegetation was not too great.

Separability of Classes. Divergence of these cluster groupings was calculated to obtain a measure of the similarity between the classes. Divergence indicated the similarity of pair groupings. All possible combinations of classes provide information necessary for combining, remaining as distinct or eliminating classes.

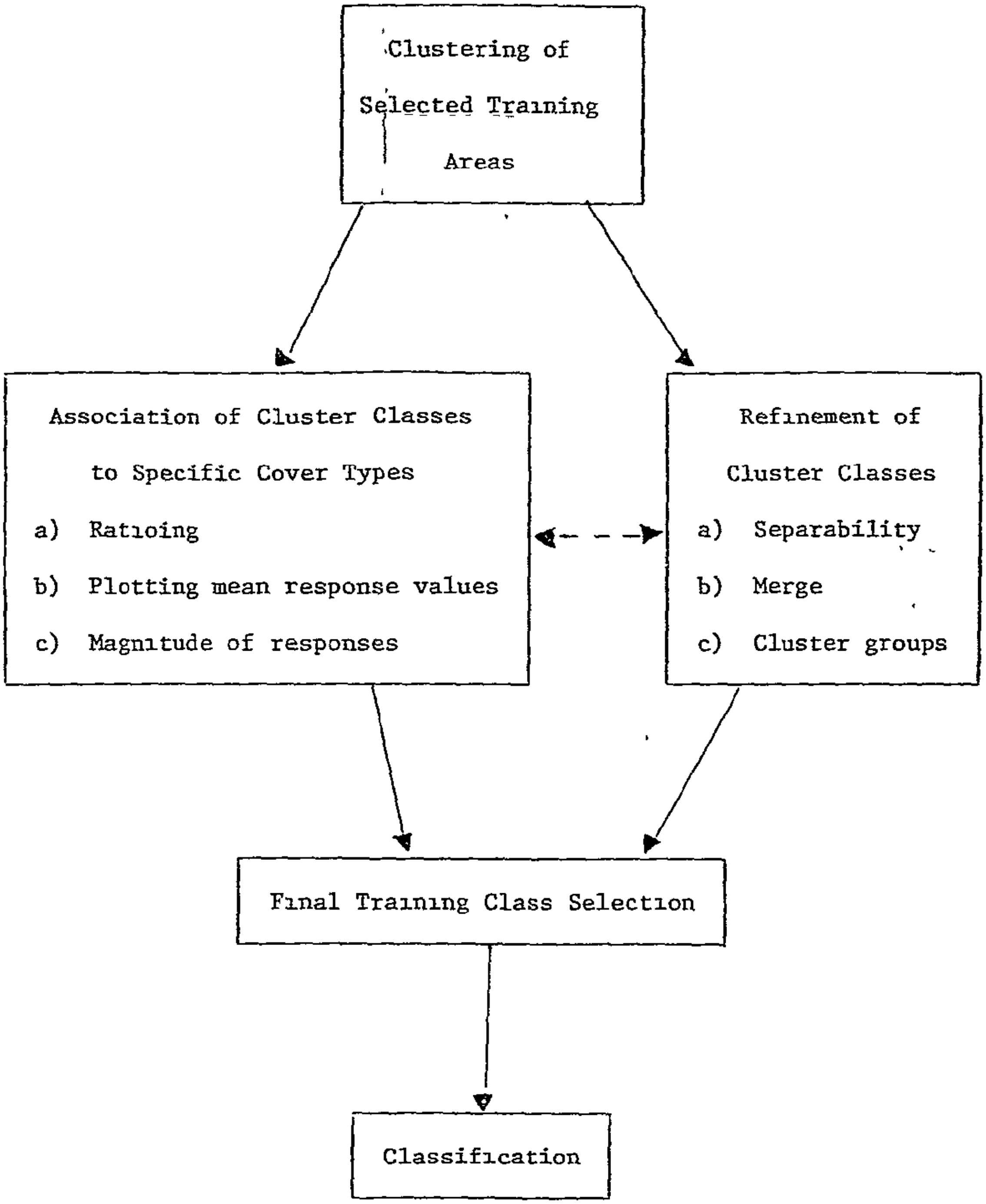


Figure 3. General analysis procedure implemented by LARSYS functions

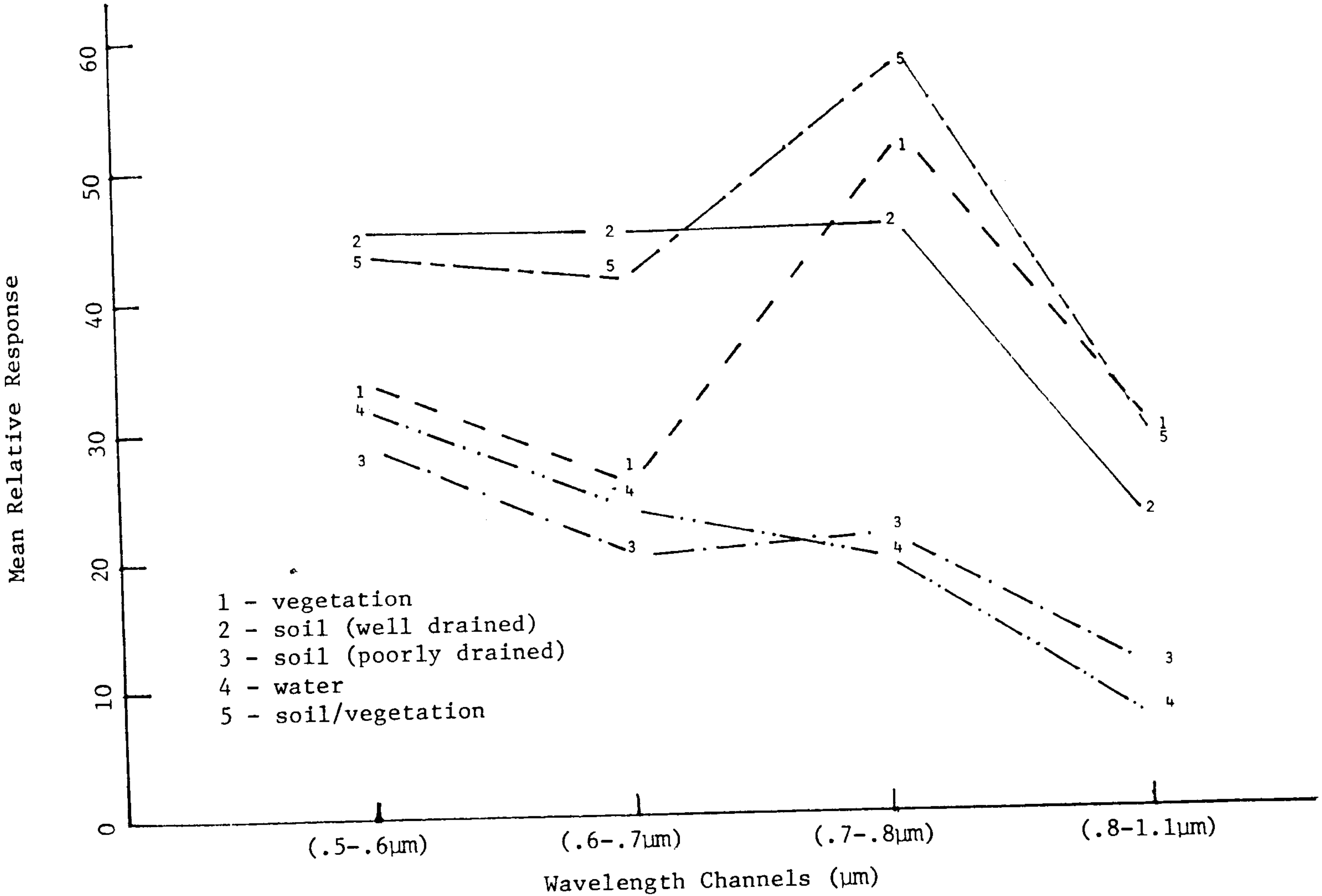


Figure 4. Representative responses of soil, water, and soil/vegetation spectral classes.

Final Training Class Selection. Information obtained from divergence measurements, ratioing, plotting, and notation of relative reflectance responses was used to define a statistical set of data points representing the area to be classified. Creation of statistical distributions most representative of the overall response is of crucial importance to correct classification. When spectral distributions are confused, the classifier will fail to separate accurately the data. Well defined separable distributions must be established if an accurate classification is the desired result. The classifier also assumes classes are normally distributed with mean and variance which further necessitates closely analyzing the final training statistics.

Classification. A Gaussian maximum likelihood classifier was used in all four analysis procedures. The results of the classification were written on a magnetic data tape which could then be accessed for displaying part or all of the area. The data tape can be read to produce the classification in the form of an alphanumeric map image, a gray scale image and/or tabular output.

The specific classification procedures deviated in the method of selecting training points for statistical analysis and in their application to the area. A description of the variations within each analysis procedure follows.

<u>Classification One</u>.

Training sites consisting of approximately 1% of the data were chosen within each parent material with at least one training site located within each parent material. By previous field inspection and notation of transitions on the false color image training sites were selected that appeared most representative of the area. Training areas were located by a coordinate system of lines and columns which designated the appropriate data points within the county.

Eleven blocks were clustered within the outwash area; seven blocks were clustered in the rolling moraine till, seven in the outwash over till, four in the lacustrine, two in the till (Alfisol) and one in the till (Mollisol). Approximately 7,000 total points were clustered in all the areas. Ten to thirteen cluster classes were specified per block, depending on the apparent spectral variability within each area.

The resulting cluster classes were identified as vegetation, soil, water or some combination of cover types based on the previously described analysis procedures. Urban classes and related spectral responses were largely ignored because they were of minimal area in the county and were not of interest in soil characterization.

Spectral classes from all parent materials were merged together into one set of means and covariances. Through a process of merging and divergent measurements, a distinct set of spectral classes resulted. Ignoring the parent material delineations the classifier categorized each data point from the county into one spectral class developed from countywide sampling.

Classification Two.

A systematic sampling of data points for compilation of training statistics characterized the second classification procedure. Systematic samples indicate all ranges of responses if they are significantly large enough or the sampling increment is high enough.

A one percent sampling (eleventh line and column) approximated the size of the first sampling and produced a set of eighteen means and their associated covariances. Increments of six lines were avoided because of the possibility of error due to scanner noise, as previously described. Parent materials were not considered in the systematic sampling of data points nor in the resulting classification. Parent materials were disregarded to test if a significant increase in accuracy would occur when the areas were delineated in classification.

Classification Three.

Spectral samples clustered in classification one were again used in classification three. Data points selected for training were combined only within parent material areas. These numbers of points varied with size of the area, therefore, a larger area would be represented by a larger number of points. Similar spectral classes were combined if they represented the same cover type. Soil responses from other parent material areas in some cases were quite similar, but the property of the classifier made it possible to retain those classes as unique within the same classification algorithm.

By the use of a decision tree design each data point was not tested against all other data points in all other spectral classes but rather was tested against only those classes formed from spectral information within a particular parent material area. Sixty statistical classes were contained at the root node from which 6 stem nodes each representing a parent material projected. These nodes were equidistant from the root node, therefore, they constituted one layer within the decision tree design. Consisting of a set of spectral classes each node was used to discriminate which classes would be used within a designated parent material area. A Gaussian maximum likelihood rule was still used to classify points although the tree design was used to discriminate the number of classes used in each unique area.

One channel or a combination of channels could be used in the layered approach for either discriminating parent material or classifying data points. Of the 60 sets of means and covariances six classes consisted only of a fifth channel which was used as a designator of parent materials. These six classes were previously mentioned as the first layer in the classification scheme. Remaining classes of Landsat data contained in the root node were compared to each of the stem nodes. Each parent material designator specified a unique set of statistical classes to be used in classifying only that parent material. The process by which the classifier proceeded is shown in Figure 5. Stem nodes and their respective classes were prespecified in the classification program.

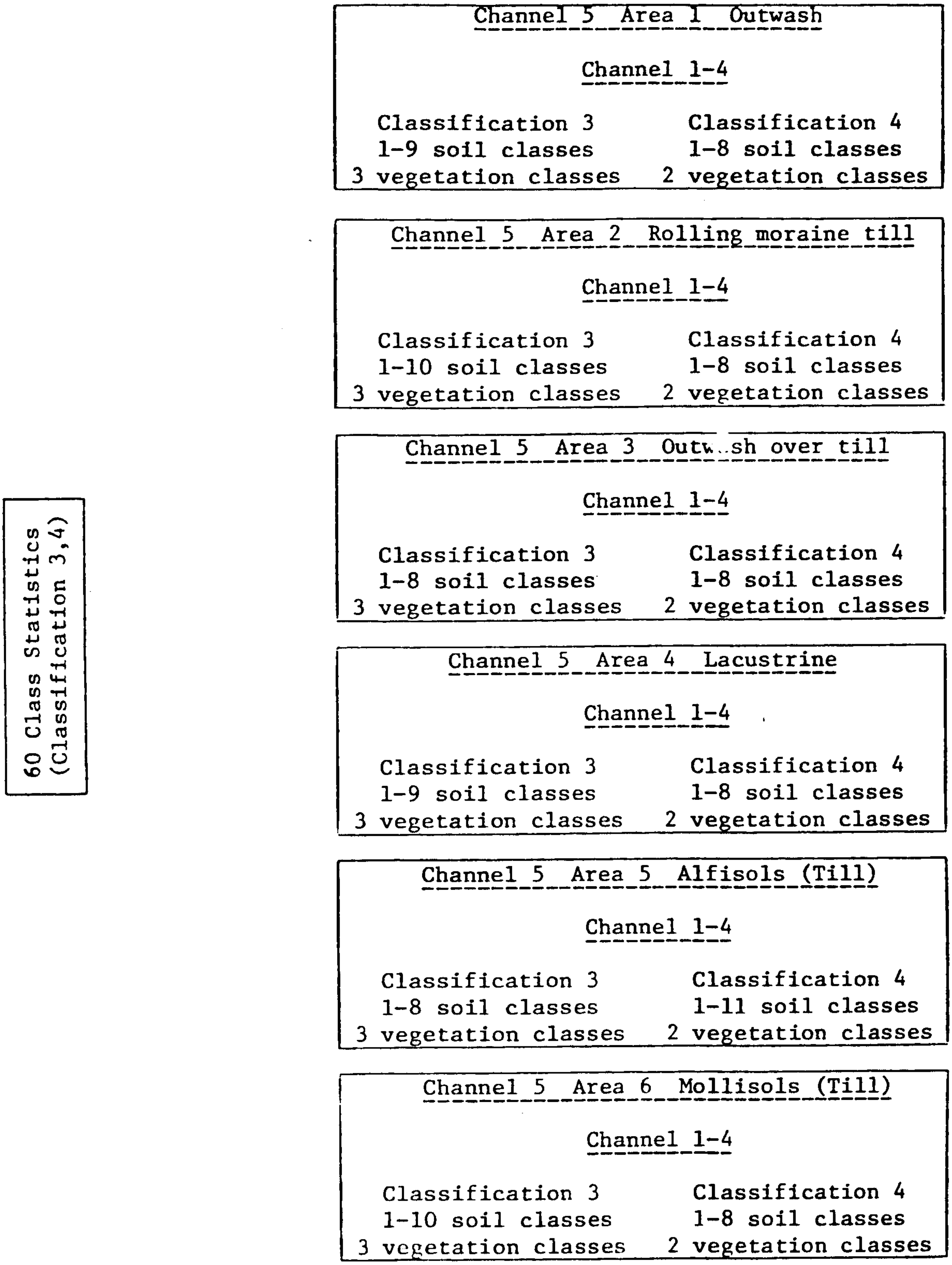


Figure 5. Tree design used in classification procedure of Jasper County spectral soil maps.

The ability of the classifier to use only 60 classes limited complete freedom in spectral definition. Soils were of primary importance in the investigation, thus, it was decided to combine vegetation from all areas and classify using only three vegetation classes grouped from across the county. Again the classifier used approximately 1% of the data within the county to train the classifier.

Classification Four.

Consideration of parent materials was integrated into the last analysis and classification. Irregular boundaries of the six parent material delineations made it extremely difficult to record all points manually within each area; therefore, a FORTRAN program was devised to locate every fifth line and column coordinate point within each parent material area. This sampling technique involved approximately a four percent sample of the county. An increment of five was used to insure adequate sampling and avoid six line noise. These line and column coordinates were used to cluster each entire parent material area. It was decided that thirteen cluster classes would be the maximum number asked for A smaller number would not adequately represent the ground scene, and a larger number may leave some spectral classes with too few points to be considered a good statistical sampling. A separate set of means and covariances was generated for each parent material. Vegetation classes, soil and scattered vegetation classes were identified by the same process described in the previous classifications. The four percent sampling was used in the layered design to produce a county spectral classification based on spectral probabilities from six different sets of statistical distributions. The design of the decision tree was identical to classification three except different spectral classes were used to compile the tree.

Evaluation.

Field Observation. Evaluation of classifications was accomplished by comparison of completed classifications to the mapped quarter sections. Three soil scientists comprised of one SCS soil scientist and two soil science graduate students mapped the quarter sections with the specific objective of mapping .45 ha delineations or larger. Normal mapping procedures were used to investigate the quarter sections. Each quarter section was located and position noted on the photograph. By traversing the land and taking sufficient borings to identify drainage patterns and textures, map units were delineated on the aerial photographs. Underlying calcarious till was identified by applying acid and observing if any reaction were present. The color chart was used to determine Mollic or Alfisol horizon colors. After investigation of surface and horizons, map units of .45 hectares or more were noted on the field sheets. Each quarter section was arbitrarily divided into three sections and mapped by one of the investigators. After the quarter section was traversed, soil characteristics were discussed and questionable areas were revisited. The final soil map was a combination of observations from all individuals. The northern part of the county was not chosen for evaluation because the distance was prohibitive in the investigation. Mapping of these quarter sections was done prior to computer analysis so bias in soil mapping could be avoided. The completed soil maps were used to evaluate the spectral classification.

Correlation to Map Units at Randomly Selected Sites. An electrostatic dot matrix plotter was used to produce individual plots of the mapped quarter sections that would be used in the evaluative procedures. Copies of these classifications were also reproduced on acetate to enable overlaying on the photograph. All spectral classes were graphed as to their relative spectral response across the four Landsat spectral bands, and copies were provided for each analyst. Analysts were asked to compare each classification to the soil maps and rate the classifications as to their correspondence to the maps. The two most representative classifications would be used in field checking and from this the most representative classification would be chosen.

RESULTS AND DISCUSSION

The four classifications were completed and evaluated by comparison to previously determined randomly selected sites within Jasper County. The following is a summary of the results of the methodology used in the Jasper County classification procedures.

Result of Registration

Difficulties in fitting the rectified halftone positives to the registered Landsat data prompted a registration of Jasper County using the rectified halftone positives as a base rather than the black and white panchromatic unrectified photographs. The rectified halftone positives, when used for registration, will not provide a better correlation between the two images, i.e., Landsat and halftones. However, with the use of halftones in conjunction with the Landsat classification, both must be registered to the same standard. As with the unrectified photographs, error was predicted to be no more than thirteen meters displacement.

Using rectified photographs should have eliminated some error due to crabbing and scale differences in blocking the photographs. However, because the halftones were trimmed to less than 20% overlap, difficulty is being encountered in the blocking procedure. When registration to the halftone positives is completed, the data points will be reclassified using the most accurate of the four statistical distributions.

Parent Materials Map. The 32 level histogrammed false color image proved to be more detailed than necessary for preparation of a parent materials map. Although the fine clicing of the spectral distribution provided more information, becuase of difficulty in visually interpreting the color levels (minute differences were not easily discernible) fewer defined levels would be more reasonable.

Field Mapping of Quarter Sections. The map units were recorded on aerial photographs at 3 cm to 1 km which were evaluated by four soils analysts. Mapping of the quarter sections required approximately two weeks of field worl to complete.

Random selection resulted in the outwash quarter sections occurring in the same section while two other quarter sections occurred side by side in the other parent materials (Figure 6). The occurrence was advantageous in that mapping the entire section was easier by eliminating the need to travel to four different locations, but abundance of wooded lots and pastures narrowed the area that could be used for spectral evaluation of soils. One disadvantage of MSS data is the inability to obtain soil responses through trees, or dense vegetation such as maturing crops and pastures.

The completed soil maps of the quarter sections (Figures 7-13) display a wide variety of soils. The outwash section, although primarily covered by vegetation, ranged from excessively well drained Plainfield sand to various histic soils such as Houghton and Adrian. The lacustrine map units ranged from well drained to poorly drained soils characterized by

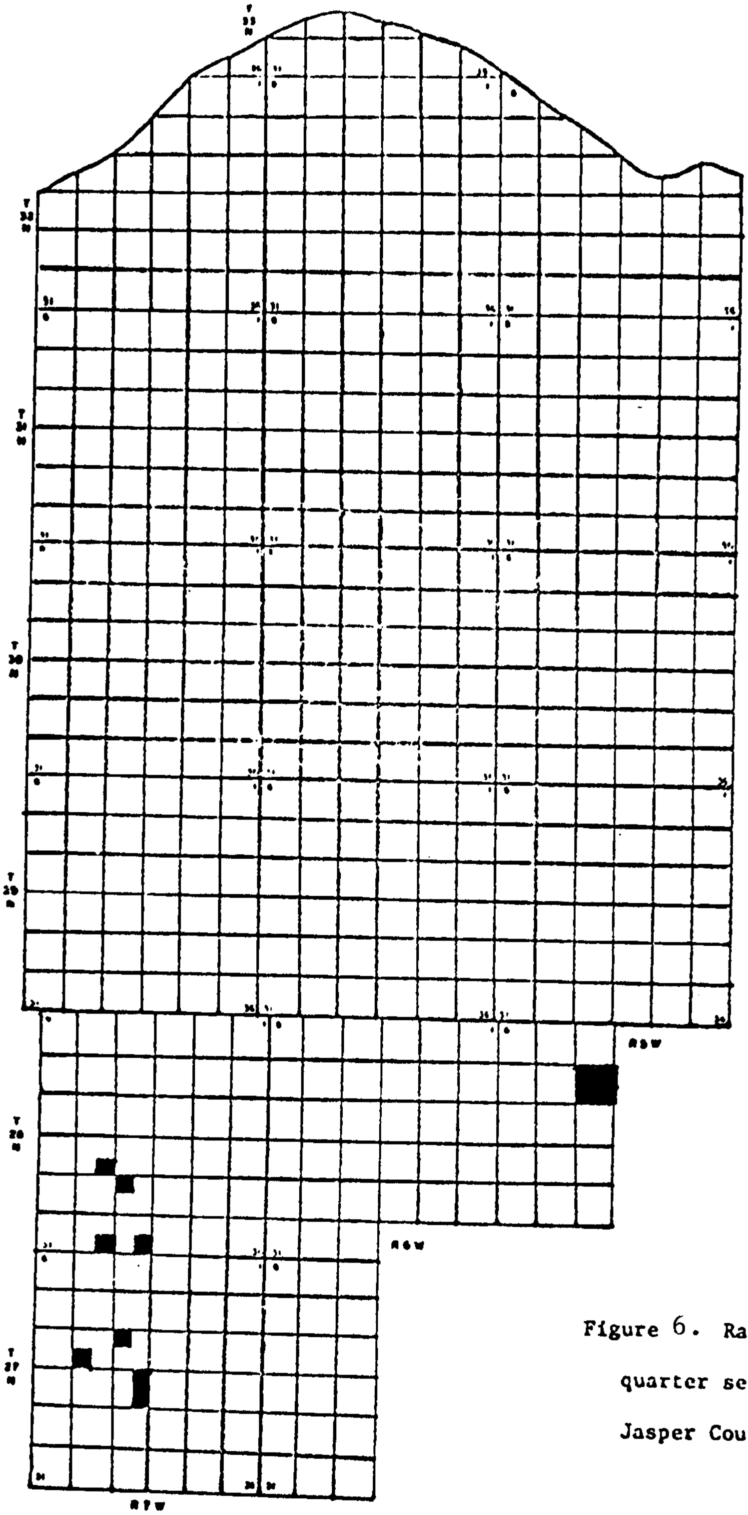


Figure 6. Randomly selected quarter sections within Jasper County.

A-C - A-C profile

Co-Corwin, fine-loamy, mixed, mesic Typic Argiudolls (well drained)
Od-Odell, fine-loamy, mixed, mesic Aquic Argiudolls (somewhat poorly drained)
Wo-Wolcott, fine-loamy, mixed, mesic Typic Haplaquolls (poorly drained)

Θ - Bedrock 1 meter

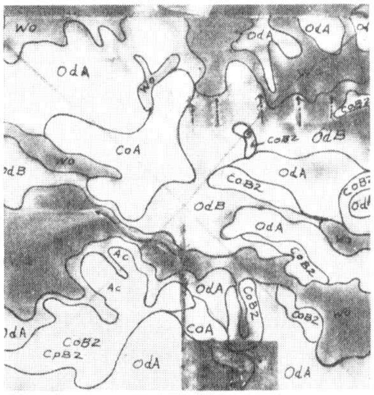


Figure 7. Till parent material
T27N R7W SW¼ Sec 20

Od-Odell, fine-loamy, mixed, mesic Aquic Argiudolls (somewhat poorly drained)
Pc-Parr, fine-loamy, mixed, mesic Typic Argiudolls (well drained)

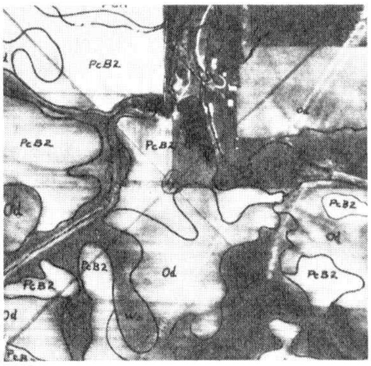
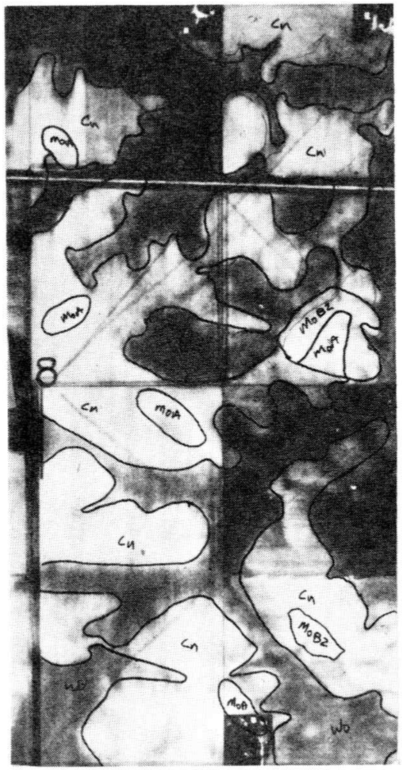


Figure 8. Till parent material
T27N R7W NW¼ Sec 21



Cn-Conover, fine-loamy, mixed, mesic Udollic Ochraqualfs (somewhat poorly drained)
Mo-Montmorenci, fine-loamy, mixed, mesic Aquollic Hapludalfs (moderately well drained)
Wo-Wolcott, fine-loamy, mixed, mesic Typic Haplaquolls (poorly drained)

Figure 9. Till parent material T27N R7W E½ Sec 28.

Al-Alvin, coarse-loamy, mixed, mesic Typic Hapludalfs (moderately well drained)
Ch-Chelsea, mixed, mesic Alfic Udipsamments (excessively drained)
Rr-Rensselaer, fine-loamy, mixed, mesic Typic Argiaquolls (poorly drained)
St-Starks, fine-silty, mixed, mesic Aeric Ochraqualfs (somewhat poorly drained)

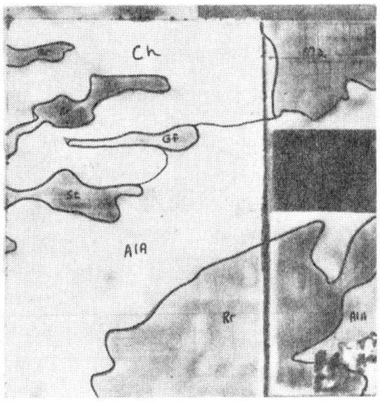


Figure 10. Lacustrine parent material T28N R7W SE¼ Sec 23.

Al-Alvin, coarse-loamy, mixed, mesic Typic Hapludalfs (moderately well drained)
Dr-Darroch, fine-silty, mixed, mesic Aquic Argiudolls (somewhat poorly drained)
Ma-Mahalasville, fine-silty, mixed, mesic Typic Argiaquolls (poorly drained)
Ro-Roby, coarse-loamy, mixed, mesic Aquic Hapludalfs (somewhat poorly drained)
Rr-Rensselaer, fine-loamy, mixed, mesic Typic Argiaquolls (poorly drained)

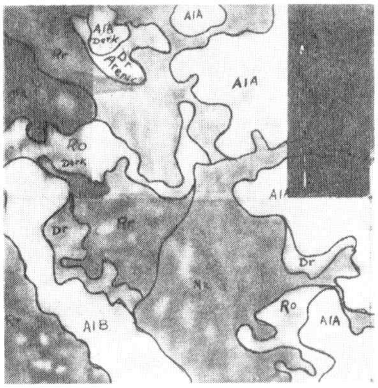


Figure 11. Lacustrine parent material T28N R7W NE½ Sec 28.

Dk-Dickinson, coarse-loamy, mixed, mesic Typic Haplaquolls
(excessively drained)

Dr-Darroch, fine-loamy, mixed, mesic Typic Hapludalfs
(somewhat poorly drained)

Rr- Rensselaer, fine-loamy, mixed, mesic Typic Argiaquolls
(poorly drained)

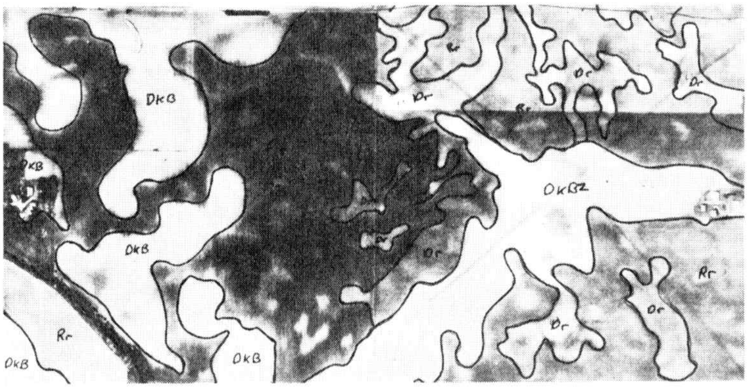


Figure 12. Lacustrine parent material
T28N R7W S½ Sec 32

Ad-Adrian, sandy or sandy skeletal, mixed, euic, mesic Terric Medisaprists (very poorly drained)
Ba-Brady, coarse-loamy, mixed, mesic Aquollic Hapludalfs (somewhat poorly drained)
Gf-Gilford, coarse-loamy, mixed, mesic Typic Haplaquolls (poorly drained)
Ho-Houghton, euic, mesic Typic Medisaprists (very poorly drained)
Md-Maumee, sandy, mixed, mesic Typic Haplaquolls (poorly drained)
Mr-Morocco, mixed, mesic Aquic Udipsamments (somewhat poorly drained)
Pn-Plainfield, mixed, mesic, Typic Udipsamments (excessively drained)

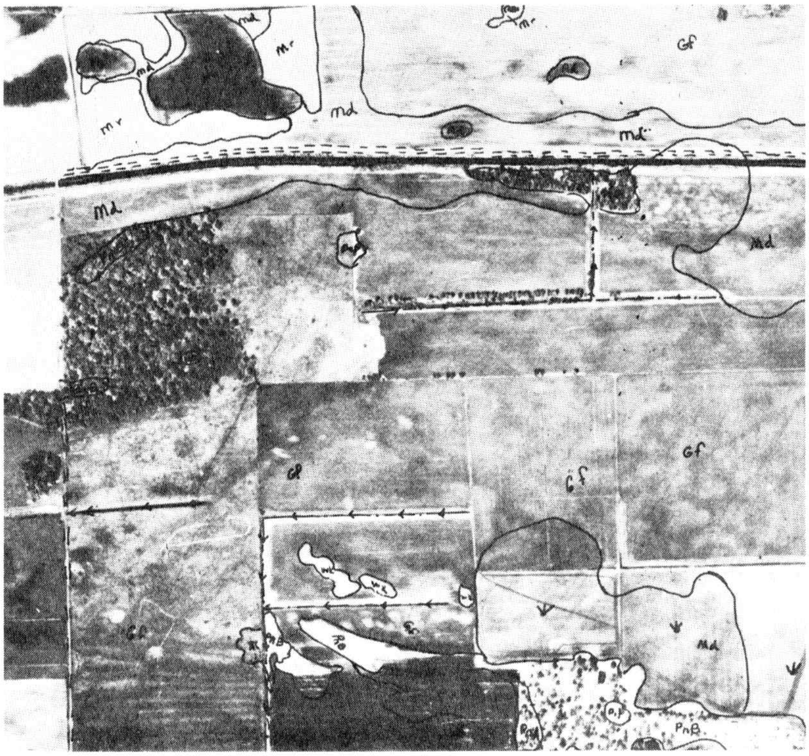


Figure 13. Outwash parent material, T23N R5W Sec 28.

fine sandy loam soils to silty clay textures. Till areas also ran from well to poorly drained profiles with primarily silt loam textures. In western till portions of the county bedrock occurred within 1 meter of the surface (this being evidence of the coral reefs discussed earlier).

Results of Classification

Four separate classifications of Jasper County were created. Of the four, two were chosen as the most representative of county soils. The following gives an indication of each classification performance.

Classification One. All block clusters resulted in at least two vegetative responses that when tested by a divergence measurement proved to be spectrally separable. These vegetative responses generally were representative of wooded areas of crops and pastures. A wide variety of soil responses were identified, but many of these classes were eventually merged when minimal distances were found for their divergence values. Water responses were not considered of major importance. Because there were no extensive bodies of water except for scattered borrow pits along Interstate 65, their response grouped with that of poorly drained soils such as the muck areas in the north and southeast. Urban areas were not of sufficient size to consider them in a unique spectral stratification and were not of interest in characterization of soils. Urban areas were classified as vegetation because of the abundance of trees and grassed areas with cities and towns.

An overabundance of representative vegetation responses, which were not of importance, were eliminated by tolerating a lower divergence value between pairs of vegetation classes than for pairs of soils classes. That is, vegetative response classes were grouped together that were not as spectrally similar as soils classes. In this process vegetation distributions became large with wide variances which resulted in detriment to overall classification accuracy. Overall the distributions became too large and variant when classes were combined from across the county. If vegetation were left as discrete classes, correlation of soil, vegetation and combination soil-vegetation responses could be investigated.

Over 65 statistical distributions were combined from all parent materials which resulted in 18 spectrally distinct classes. Of these 18 classes six displayed vegetation responses, nine were soils and the remaining three had characteristics of both soil and vegetation. Since these three classes had characteristics of soil, it was thought that information from these classes would contribute to identification of soils; therefore, they were considered part of the soil response group. No consideration of parent material delineations was taken either in the merging of cluster classes or in classification of the county.

Of the four analysis techniques the first spectral classification was the least representative of the mapped quarter sections. The most accurately classified of the twelve areas occurred in the till (Mollisol) parent material. Spectral soil classes were more correlated to map units in the till area than in the other representative areas.

Some averaging occurred by combining cluster groups together. Distinctiveness of better drained areas was lost as well as more poorly drained soil responses. For example, the Odell, a somewhat poorly drained, was represented by the same statistical group as Corwin, a well drained soil. Corwin and Odell have silt loam surface textures and differed in color by 10YR2/2 for Corwin compared to 10YR2/1 for Odell. Parr, another well drained silt loam with 10YR2/2 surface color, was also confused with the Odell. Due to closeness in color and drainage profiles, these soils would have been quite close spectrally; however, soil distinctness was lost when distributions from across the county were combined.

A poorly drained Wolcott soil with a silt loam surface texture and 10YR2/1 surface color did not correlate to any specific spectral class. All map units had evidence of scattered vegetation data points which were not in as great abundance as in other classifications. Figures 14 and 15 show spectral responses of soils and soil-vegetation complexes along with identified vegetation classes.

Figure 16 shows the resulting county classification from the first analysis. The overall county map is very representative of general cover types within the county. Only on fine detail maps is the classification less than adequate for defining soil series. Soils differences that indicate dramatic changes such as the organic soils are easily recognized, but the more subtle differences are confused. Borrow pits along Interstate 65 are recognizable but, as stated before, were classified as a poorly drained or histic soil.

Classification Two. A systematic clustering of prespecified lines and columns characterized the second classification scheme. By systematically sampling the entire county, data which could be overlooked by block clustering would be sampled. Unique areas of smaller than 225 ha could be bypassed since those areas are not mapped (due to the expense in establishing a soil series and the small area in relation to the county) as a soil series within a county. Those areas overlooked in a systematic sampling would not be of importance in characterization of county soils.

Identification of cluster classes resulted in eight definite soil responses, six vegetation classes and five soils with some vegetative influence. In subjective sampling, vegetated areas such as the Jasper Pulaski State Fish and Wildlife Area, wetland areas and scrub oak areas on sand ridges were generally avoided, but systematic sampling chose points throughout the county which accounted for the increased number of soil-vegetation responses. A good definition of scrub oak, wooded areas and trees and plants along creeks and rivers was the result of the second classification because these were not avoided and could be classified with actual representative data points from the area.

Evaluation of the soil maps revealed the second classification to be more representative than the first but not of the quality displayed in the third and fourth techniques. Again, difficulties were encountered with scattered data points of vegetation appearing across the map units, but not to the extent of classification one. Odell, a somewhat poorly drained soil, was again confused with the well drained soils, Parr and Corwin.

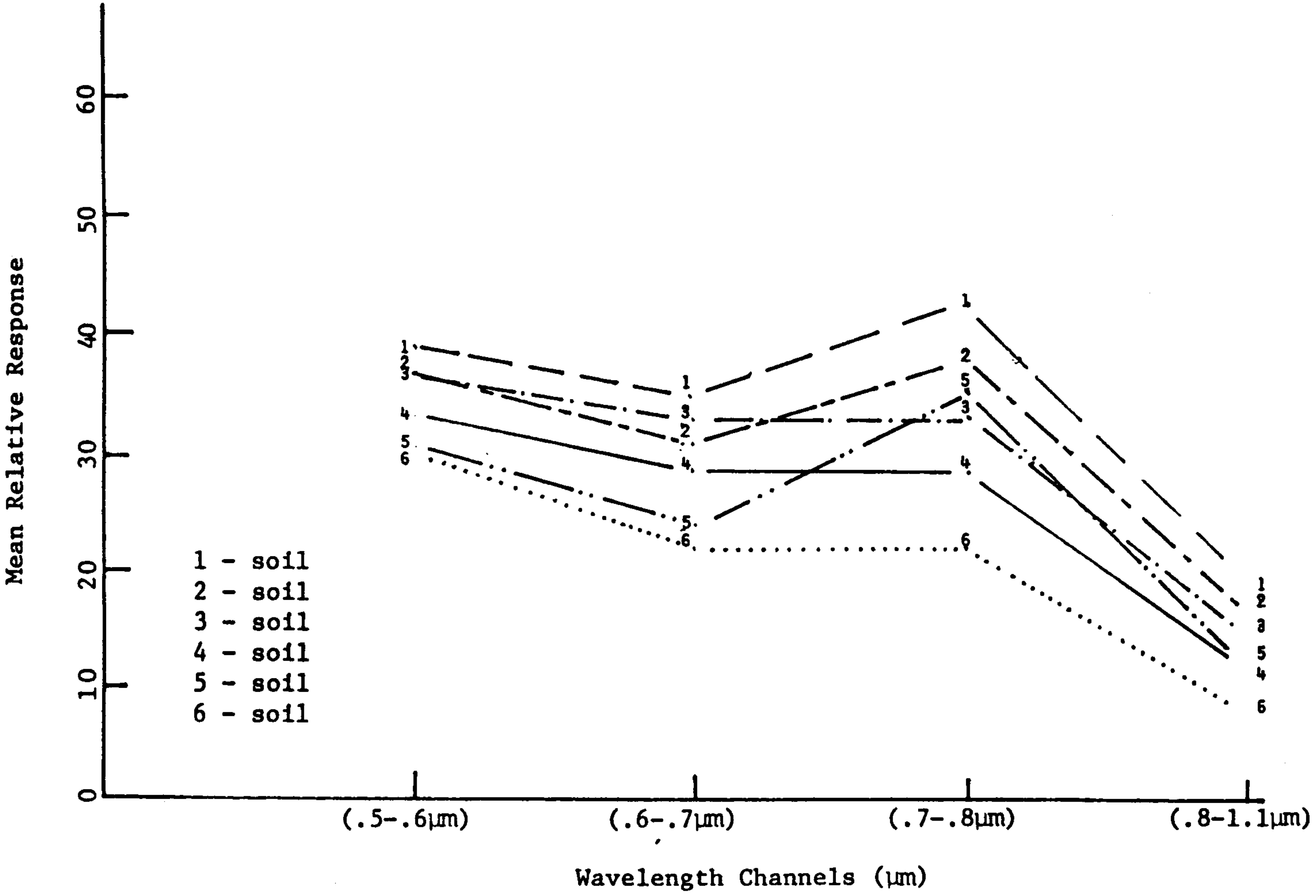


Figure 14. Soil responses for classification one.

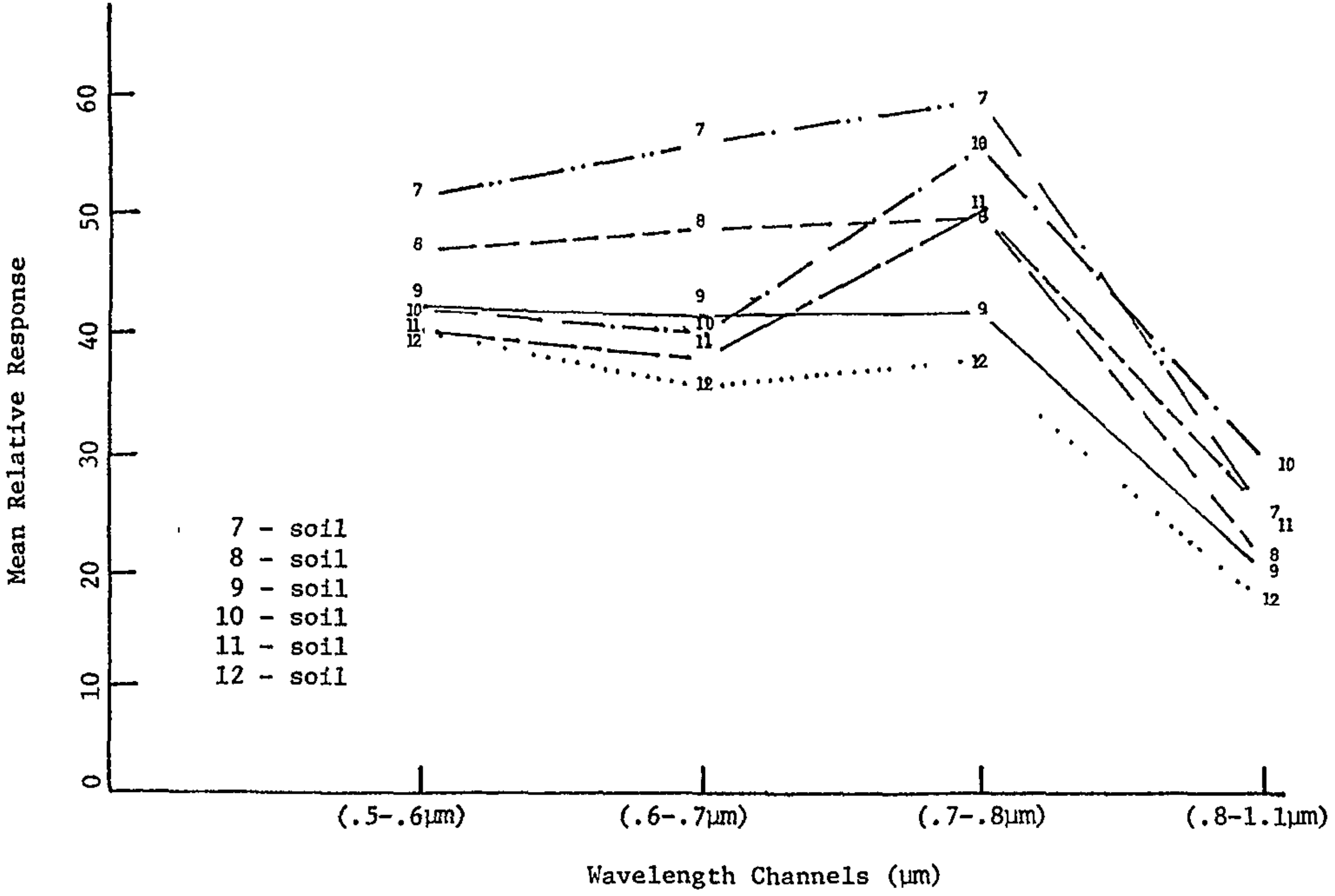


Figure 14. (Continued)

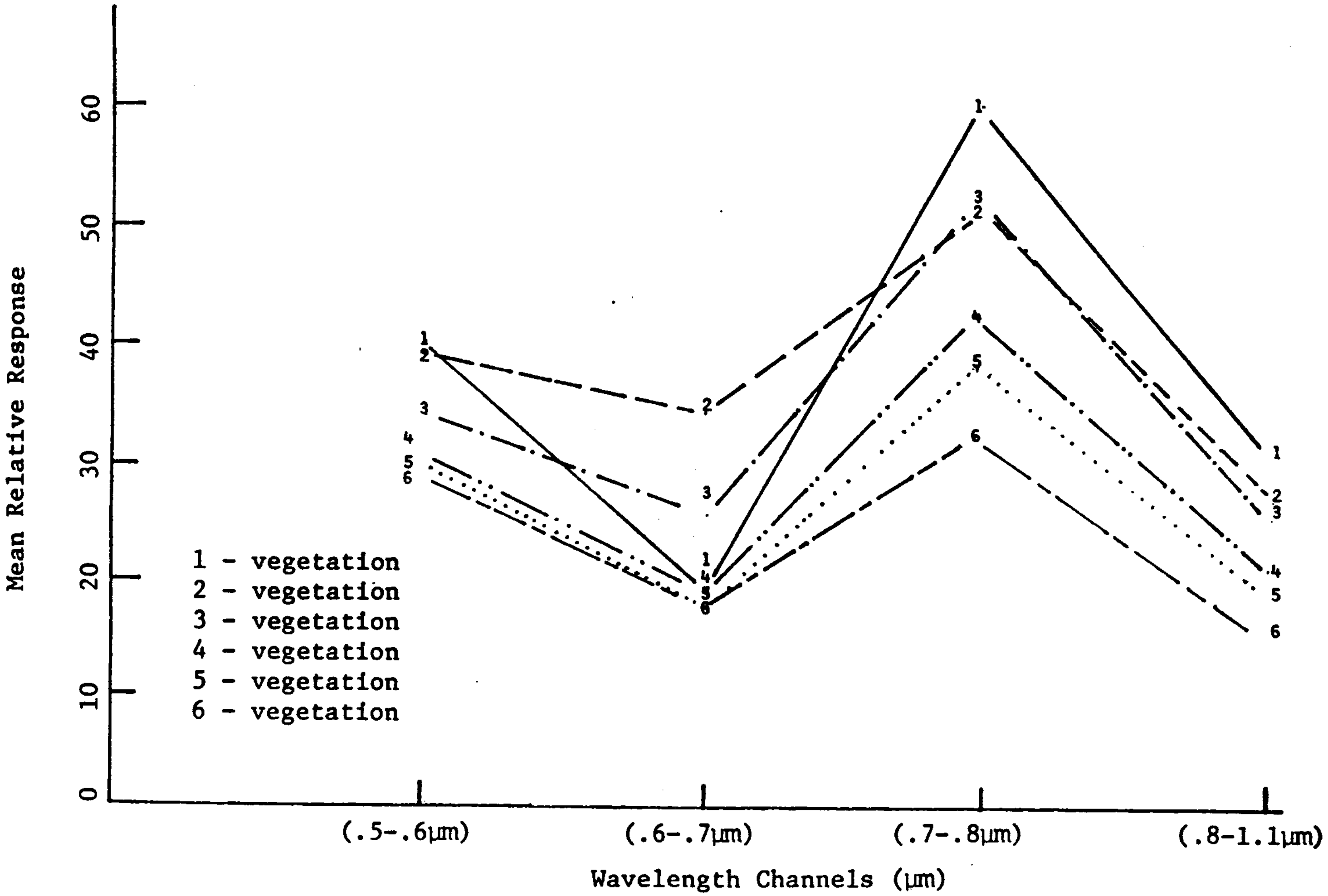


Figure 15. Vegetation responses for classification one.

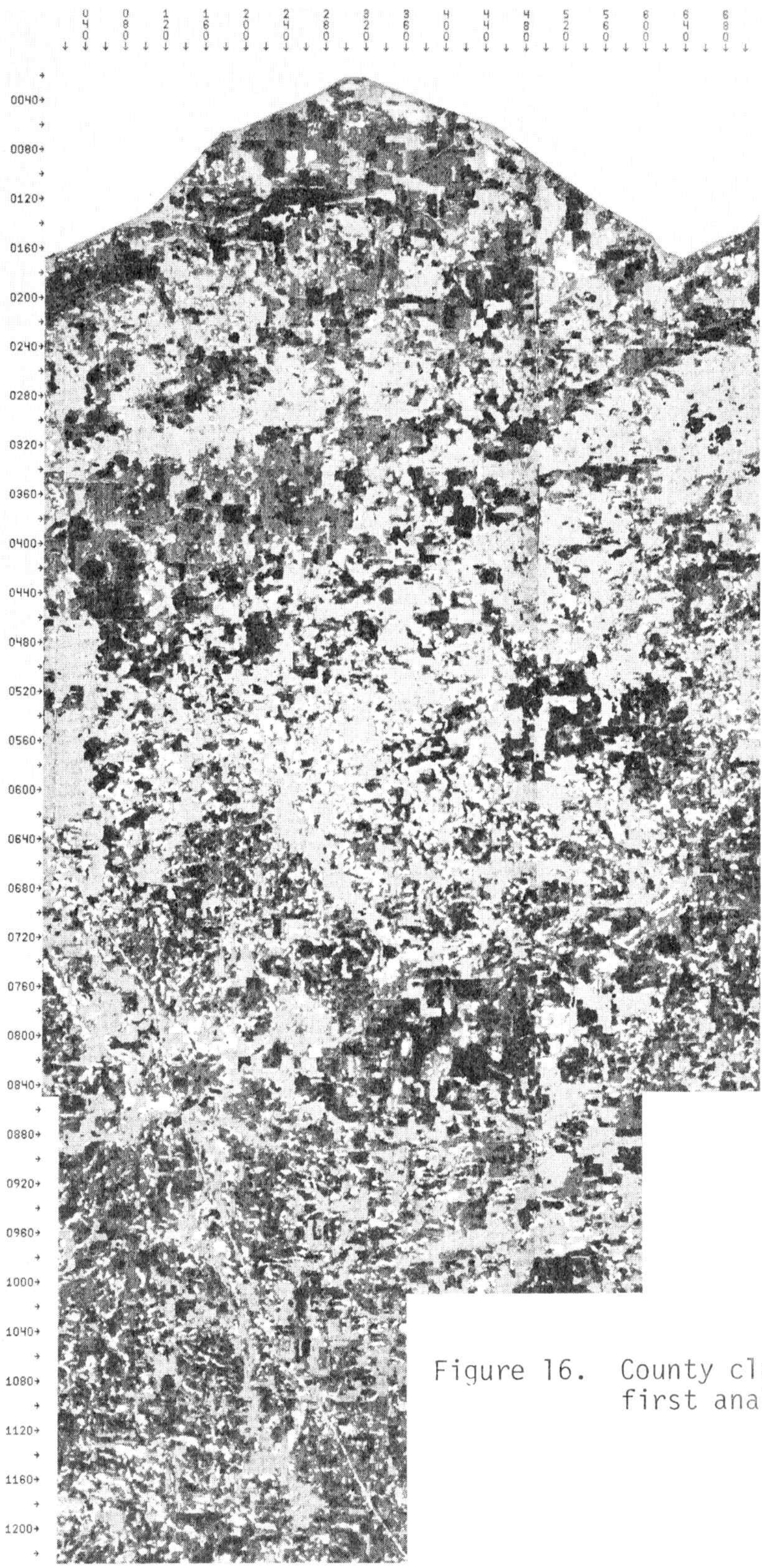


Figure 16. County classification from first analysis procedure.

Investigated scattered data points indicated characteristics of both soils and vegetation. In an attempt to improve the homogeneity of the map units, statistical distributions were altered by eliminating the combination soil-vegetation classes and reclassifying only those areas corresponding to the mapped quarter sections. Figures 17 and 18 show the graph of data before and after alteration. In general, data points previously classified as mixed soils and vegetation were classified as the surrounding soil response. Only classes displaying a relatively pure soil or vegetation response were used in reclassification.

The entire county was not reclassified because of the expense and because the reclassification was to be done on the rectified registration that was not yet completed. Although favorable results were encouraging, the quarter sections were not of sufficient size to infer the same results would occur across the county. In some areas elimination of classes could be of detriment to accurate scene identification by forcing data into classes not indicative of their true response nature. For example, training statistics developed specifically for a well drained soil would accurately identify that soil. However, if lighter responding erosion classes had no training statistics spectrally near, it could be classified with a light colored well drained soil. This could have been avoided had there been a unique spectral distribution designed to represent an eroded soil. Further research into identification of spectral classes should be attempted so the most influential parameters contributing to response properties can be determined. Large classification areas the size of a county necessitate careful selection of spectral responses that provide an optimal spectral design of the tract.

The second analysis provided better correlation with mapped soils which could be attributed to better defined, more evenly distributed spectral classes that were selected by a systematic approach.

Classification Three. By combining cluster classes only within parent materials six sets of statistical distributions were created. Each set was used to classify only within a particular parent material. The resulting set of statistical distributions contained nine soils in outwash, six soils in the rolling moraine till, seven within outwash over till, eight in the lacustrine areas, eight in the till Mollisol and seven in the till Alfisol (Figure 5). Initially, vegetation was included within each parent material, but due to the limited 60-class capability of the tree design vegetation was combined and a standard set of vegetation spectral distributions was used in each area. Modifications to the tree design and classifier has enlarged the capacity which will benefit future attempts at county characterization. The third analysis provided still better correlations than the first although some quarter sections displayed definite inaccuracies in soil representations.

The outwash over till parent material area produced rather unique spectral responses (Figure 19) in that only two classes displayed a characteristic soil response over the four channels while the remaining classes responded highly in channel three (indicative of vegetation) which leaves question as to whether there was a lot of scattered vegetation in the area at the time of the overpass or if these are unique soil responses that have not been encountered before. Only three of the major parent materials

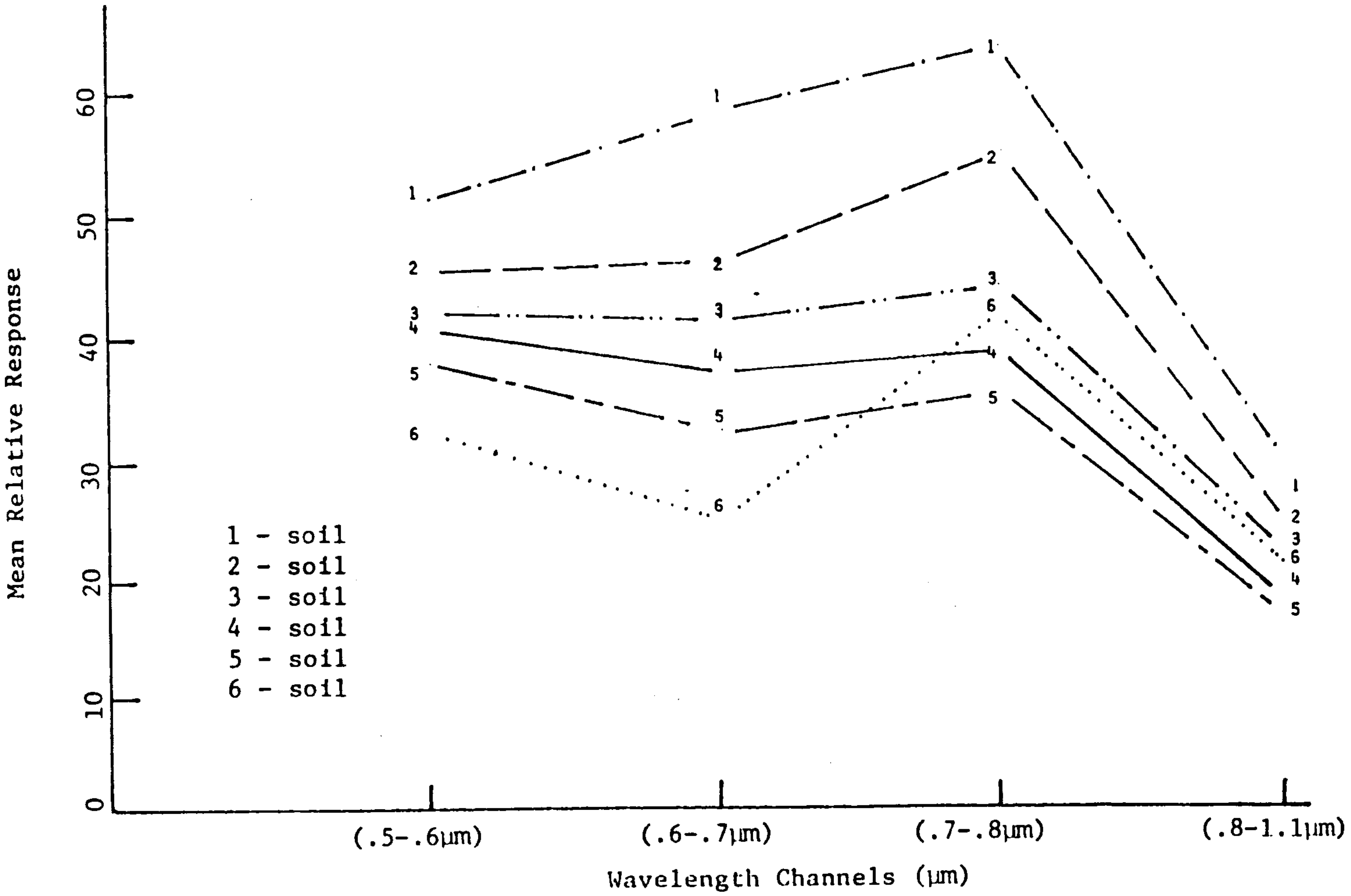


Figure 17. Soil responses of second classification.

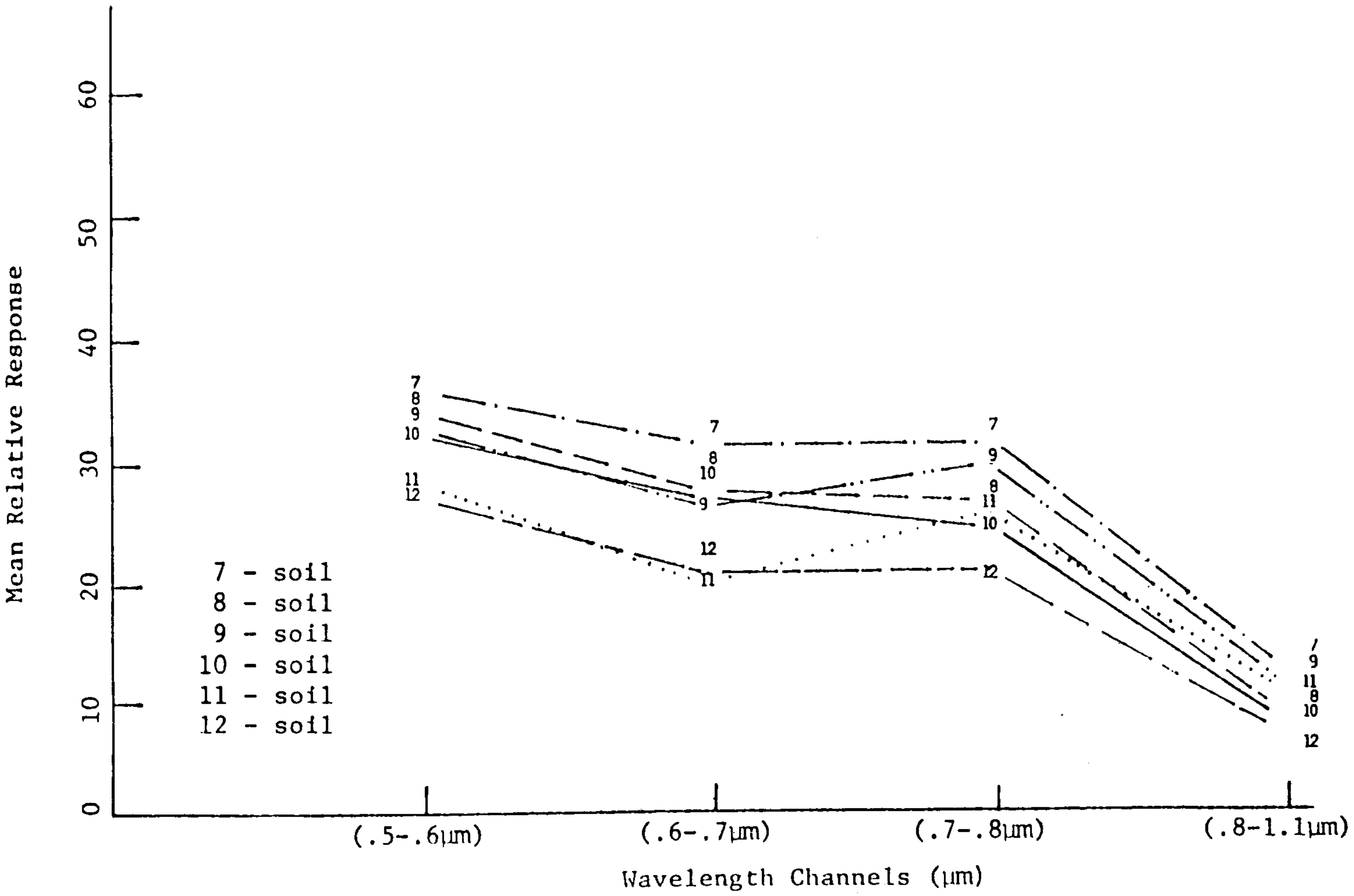


Figure 17. (Continued)

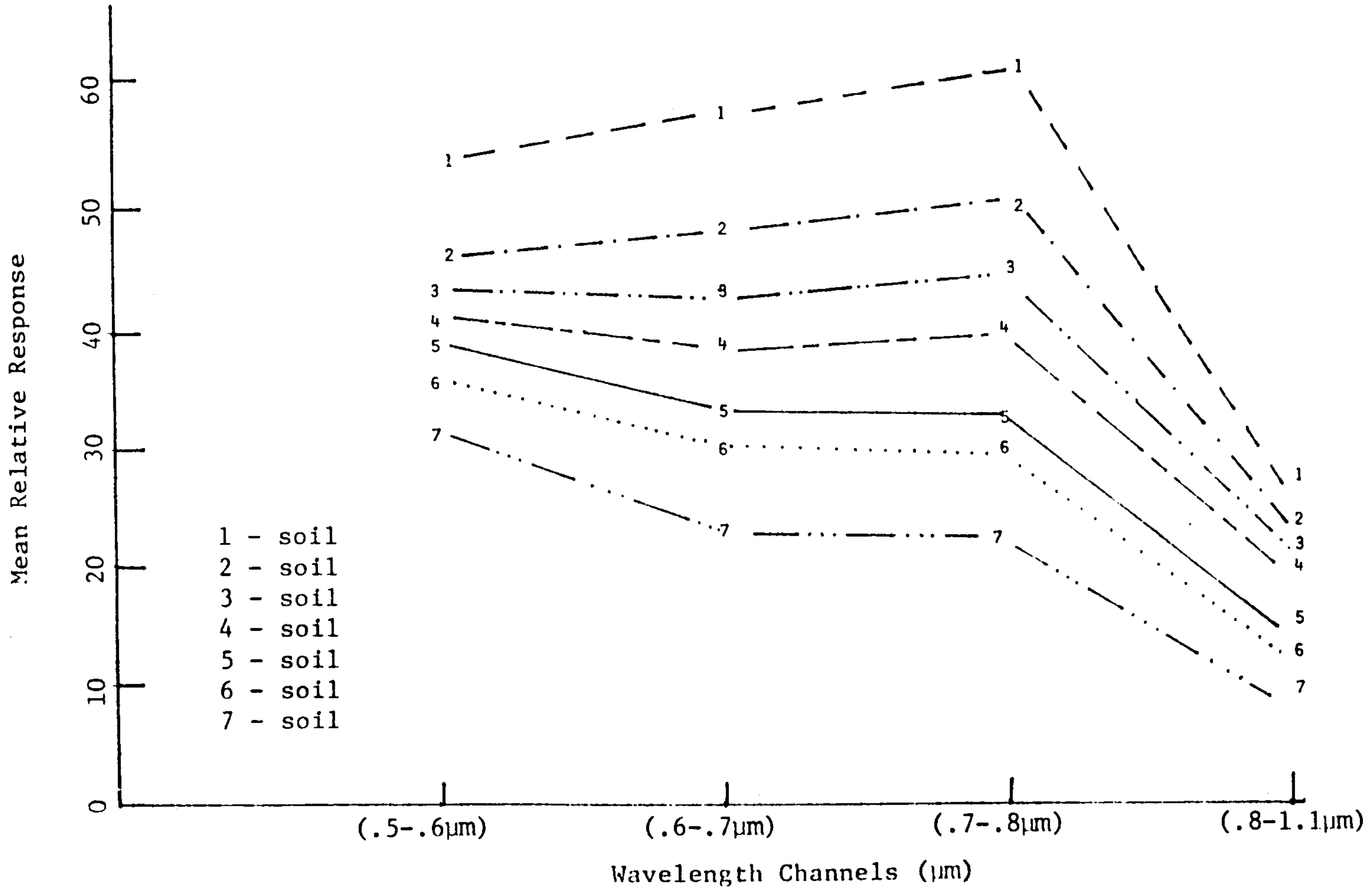


Figure 18. Soil responses of second classification after alteration of statistics.

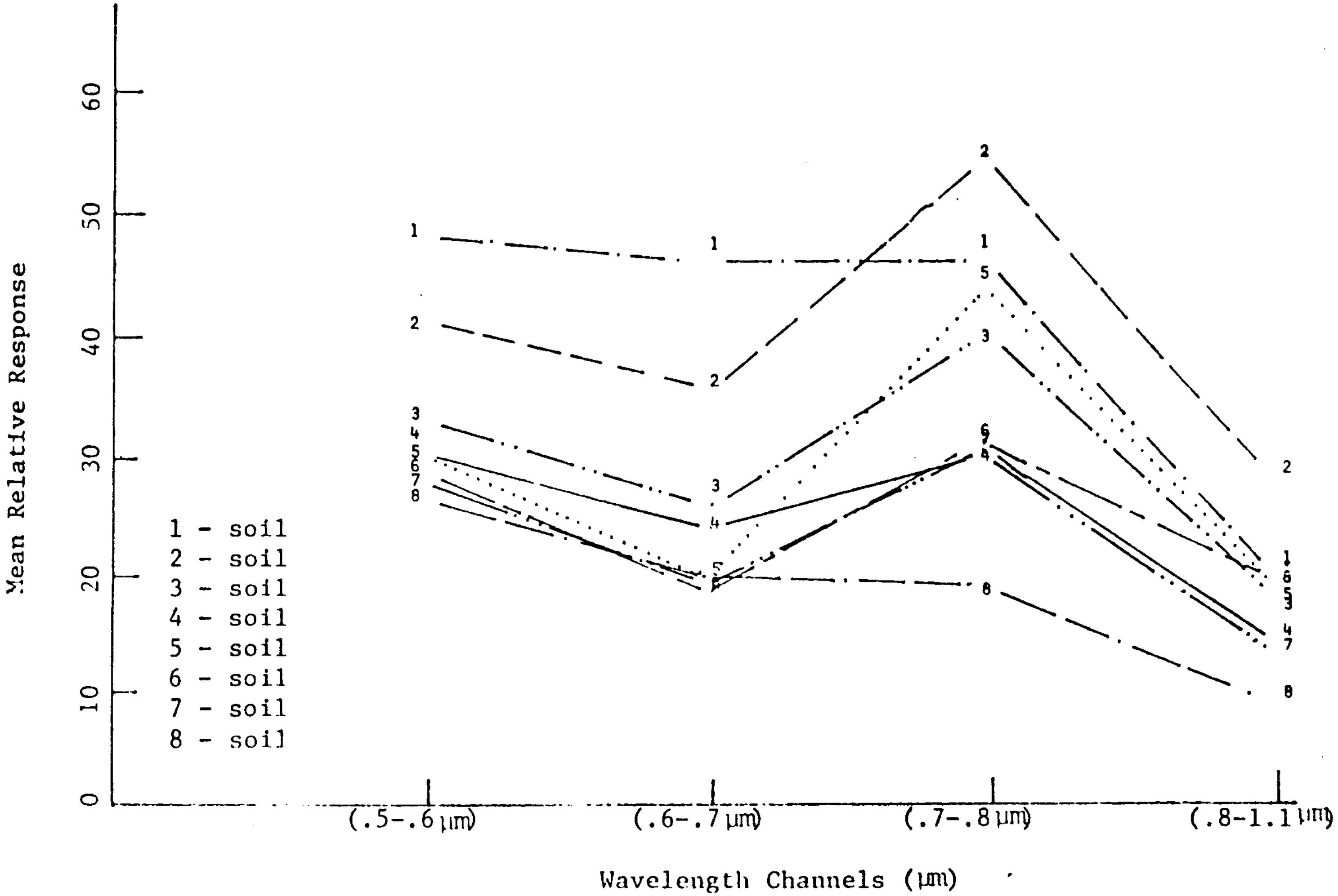


Figure 19. Soil responses in outwash over till parent material area for classification three.

had been chosen to evaluate the classification so no prepared ancillary data were available to help explain these phenomena.

In the till areas Odell and Corwin were difficult to discriminate; both reflected as the lightest soil class. In some transitions to darker poorly drained soils, such as in T27N R7W Sec20SW¼ till, Odell responded much lower spectrally than when it was associated with Parr or Corwin. It appears that Odell, a somewhat poorly drained soil, has a wide range of reflectance. Since its drainage characteristics resemble well drained and poorly drained parameters, it may be less well drained in association with poorly drained soils and better drained when associated with well drained soils. Also, data point averaging could affect these responses.

The lacustrine shows good correlations with excessively drained soils, but evidence of inclusions within the soils was not supported with ancillary data. Areas of small inclusions could have been overlooked in the initial mapping. So, areas in question should be revisited.

The outwash areas showed good definition between spectral classes and soil series. Some variability was evidenced in separation of Brady, a somewhat poorly drained silt loam with 10YR3/1 color, and Plainfield, a well drained fine sand with 10YR4/3 color. Although Brady was separated for the majority of the map units, some pixels representative of Plainfield were integrated in the map units.

Gilford, a poorly drained sandy loam with 10YR2/1 color, was completely separated from the Maumee, a poorly drained loamy fine sand with 10YR2/0 color. Other parameters than drainage characteristics must have contributed to this spectral variability. Slight differences in texture and color could also have contributed to the ability to separate these two poorly drained soils. Maumee, for the most part, appeared in depressional wet spots and could have been categorized as a very poorly drained soil which may also have contributed to separability.

Evaluation after classification suggested that again the greatest contributor to misclassification was largely due to the influence of a combination of soil-vegetation responses.

Classification Four. The last classification proved to be the most accurate of the four analysis techniques. By clustering within parent materials four percent of the data was sampled compared to a one percent sampling in the previous analysis techniques. A larger sampling provided better definition of spectral response which resulted in a more accurate classification

The county was statistically classified with 52 soil representations and two vegetation classes. Ten spectral classes were used in the outwash, twelve in the till (rolling moraine), ten in the outwash over till, nine spectral classes in the lacustrine area, thirteen identified in the till (Alfisols) and ten classes within the till Mollisol area.

Although overall classification four appeared more representative, misclassification was apparent in the outwash and lacustrine quarter sections. The lacustrine area, T28N R7W Sec32 S½, was better represented by classification three. Mixing of two spectral classes occurs in the Dickinson map units, an excessively drained fine sandy loam with 10YR2/2 surface color. Vegetation is scattered more throughout these map units in the last classification than in classification three. The outwash section, T23N R5W Sec28, which consists of large map units of Gilford and Maumee, two poorly drained soils, were not differentiated as in the previous classifications. The same occurrence was noted within the lacustrine area, where spectral responses of low responding soils were checked. The poorly drained soils were representative of the lowest reflective soil, but both graphs also revealed the next lowest responding soil as higher reflecting in the third channel. If vegetation was masking the response of soil, then perhaps bare soils within the same response group are classified to the nearest group responding as a bare soil with no vegetative influence (Figures 20, 21).

Initial success at identifying soils was based on the ability to differentiate drainage profiles; thus it was surprising to note two poorly drained soils within the same parent material. Spectral characterization of soil parameters is needed to define the extent to which each parameter contributes to overall spectral response.

Unique Characteristics of the Data. Scattered vegetation was evident across all classifications and contributed to interference with the homogeneity of all map units. These scattered vegetation-soil complexes were at first considered to not be a valid delineation. Further inspection of response values found that these data points were indeed a combination of vegetation and soil responses. Crop information from June 1973 found ninety percent of the corn and sixty percent of the soybeans were planted by early June. This gives explanation to why so many scattered data points were found in evaluations. These data should have been gathered before decisions were made regarding the date to be used in analyzing the remotely sensed data. At this time it is not known exactly how vegetation influences a soil response, that is, whether it gives an overall high response or low response or only influences the response in channel two and three. Information then cannot be extrapolated from these combination pixels as to the type of soil the vegetation is occurring on. If the combination points appear in a map unit, those points cannot be assumed to be a part of that map unit because of the possibility of inclusions occurring within the unit. The easiest way to eliminate this problem is to choose a date that is known to be relatively free of interfering ground cover. The next step would be to analyze responses to predict the soil from the combination response.

Aerial photographs were not rectified which contributed to error in matching map images. The resulting rectified halftone transparencies were used for reregistration which should produce a more accurate map representative of the county. Map quality photos should be essential for creation of registration data and map quality output.

Evaluation of Quarter Sections. Evaluation of quarter sections was, in general, a subjective approach with map units and spectral classifications being overlaid for comparison. One analyst did use a numerical approach by counting data points within each map unit and calculating

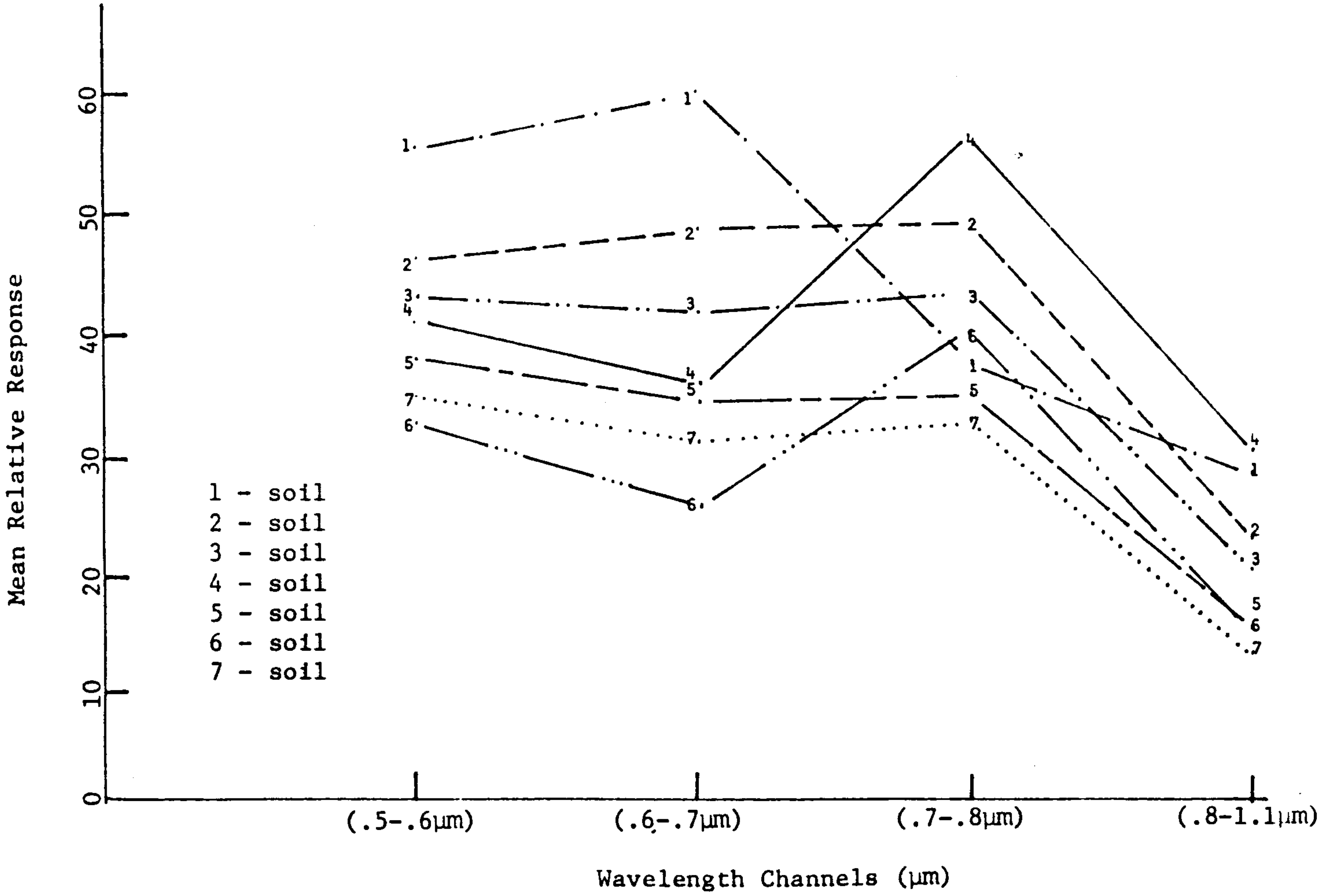


Figure 20. Classification four lacustrine soil spectral responses.

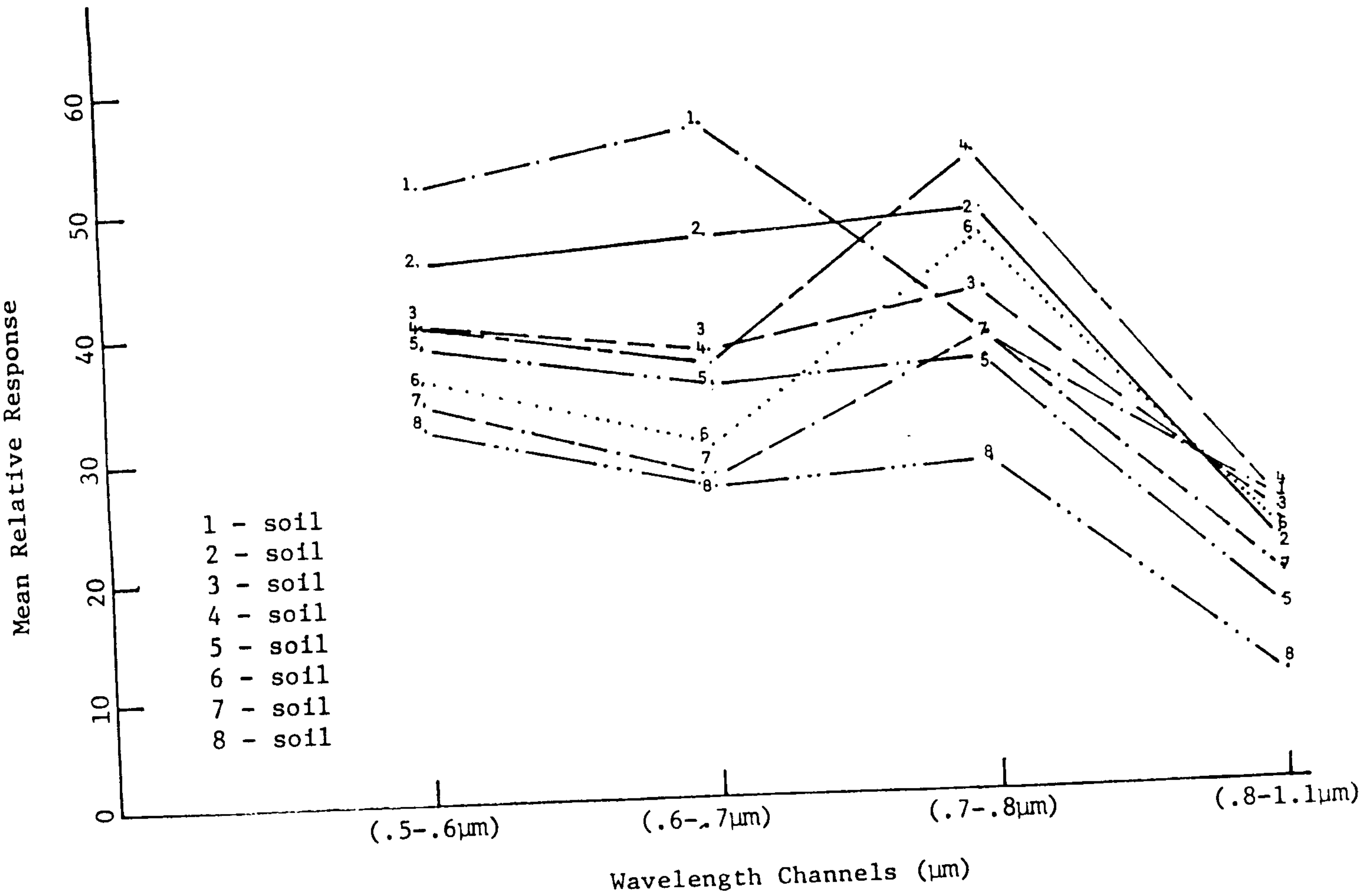


Figure 21. Soil spectral responses from outwash area, classification four.

the percent soil each spectral class represented. The purest map units or those spectral classes that represented the largest portion of any single map unit were found in the last classification. All analysts agreed that the last two classifications were the most representative of the four classification techniques.

A more quantifiable evaluative technique is necessary to provide an objective approach in selecting classifications. Bias was also integrated in the analysis techniques by the same individuals mapping the quarter sections and evaluating the classifications. By varying the individuals that mapped the quarter sections and evaluated the quarter sections, a more objective evaluation would result.

A statistical evaluation was attempted to test the validity of separating the parent materials. Both analyses (all highest responding classes and all lowest responding classes across parent materials) proved highly significant at the .01 level; therefore, the hypothesis of the homogeneity of distributions was rejected. These values may have been overly inflated due to the large number of points used in compilation of the distributions. Calculation of degrees of freedom is based on the total number of points used in the set of distributions; therefore, the large number of points contributed to the significant values. The problem was further complicated because at least six classes were needed for testing so no classes could be eliminated to reduce point size. A test more sensitive to relationships of distributions and less sensitive to point quantities is needed.

<u>Delineations Made by the Classifier</u>. Favorable correlations with the classification map were found when field observations were made. As in the past, drainage patterns and organic matter differences were found to be highly correlated to reflectance. Organic differences were evidenced by the separable histic inclusions in the north and southeast. Minor differences in texture also were evident especially in the outwash area. Again, it is not certain how much contribution each of these soil parameters make to the overall soil reflectances.

Areas of moderate to severe erosion located in the till region were found to correlate almost 100% with one spectral class. Two separate areas were checked and both gave evidence to good correlation. The second area showed large areas of erosion running east to west that when field checked were not that extensive. This could be caused by east-west bias that occurs in clustering. Clustering samples point left to right across a line; therefore, the probabilities of points lying next to one another being in the same class is slightly higher than for points lying to the north or south. Surrounding pixels may have contributed to the erosion areas which would result in exaggerated erosion classes.

The eroded class, in both areas, was not the highest responsive class. In general, the highest responding class tended to have the largest variance because it is an all inclusive class of points above a certain response. Erosion representation, since it is not the highest responding class, has definite limiters on its response range which contributes to a better defined distribution with smaller variance.

The sand ridges, in the northern part of the county, were defined by the vegetative response of the scrub oak, that occurred on the ridges. This provides the ability to map Plainfield sand, the predominant soil of the sand ridges, by delineated scrub oak areas. Areas of native vegetation or in this case scrub oak could be used to identify underlying soils if certain soils supported unique vegetation types.

A vegetation map of the county was also available through the use of the tree design processor which was used to delineate the Jasper-Pulaski Fish and Wildlife Refuge, the location of rivers and creeks, drainageways, and pastures and/or wheat fields. County roads and Interstate 65 were also visible on the final classification. Boundaries of parent materials could also be obtained and individual parent material classifications could be printed because of the nature of the layered processor (Figures 22-27).

Map products of the soils classification can be all or any part of the county at any scale. The products can be on acetate or computer printout with grey scale values, alphanumeric or symbol sets. This map quality product gives a synoptic view of Jasper County that has not been available without Landsat except through mosaicing aerial photographs.

An Augmented Procedure for the County Soil Survey. If this type of analysis has the potential to be used in soil surveying, where does it fit into the county plan for a survey? The decision to use remotely sensed data could be made at the same time the designation to initiate the soil survey is made. Data preparation and imagery analysis would then be instituted at the same time preliminary investigation was to take place. If photography were used as a base map for registration, then it must be taken in advance. If 7½ minute topographic maps are to be used for registration, photographs need not be available until the usual time. Digital analysis, evaluation, refinement, and creation of map products can also be done before soil mapping begins. Map products could then aid in beginning the soil mapping by locating spectrally similar soils, identifying inclusions, providing information to areas not readily accessible, identifying drainage profiles, locating possible areas of erosion, and identifying textural and organic differences. If a parent material or soil association map were created, this could aid in developing soil interpretations and establishing soil series within the county. Finally, the remotely sensed data could be used as a quality control for map units by identifying the percent inclusions, their extent and location. Figure 28 shows a possible augmented soil survey procedure.

Limitations and Difficulties. The greatest limitation was the interference of vegetation with soil response. Consideration of planting dates should influence the date when the remotely sensed data are chosen. Future remotely sensed data systems may not have the same difficulty as the Landsat MSS data, but now this is extremely important.

Registration is important if close correlation to resolution size elements is to be made. Aerial photography should be of map quality if good correlations are desired. The photographic imagery and remotely sensed data should be collected at approximately the same time.

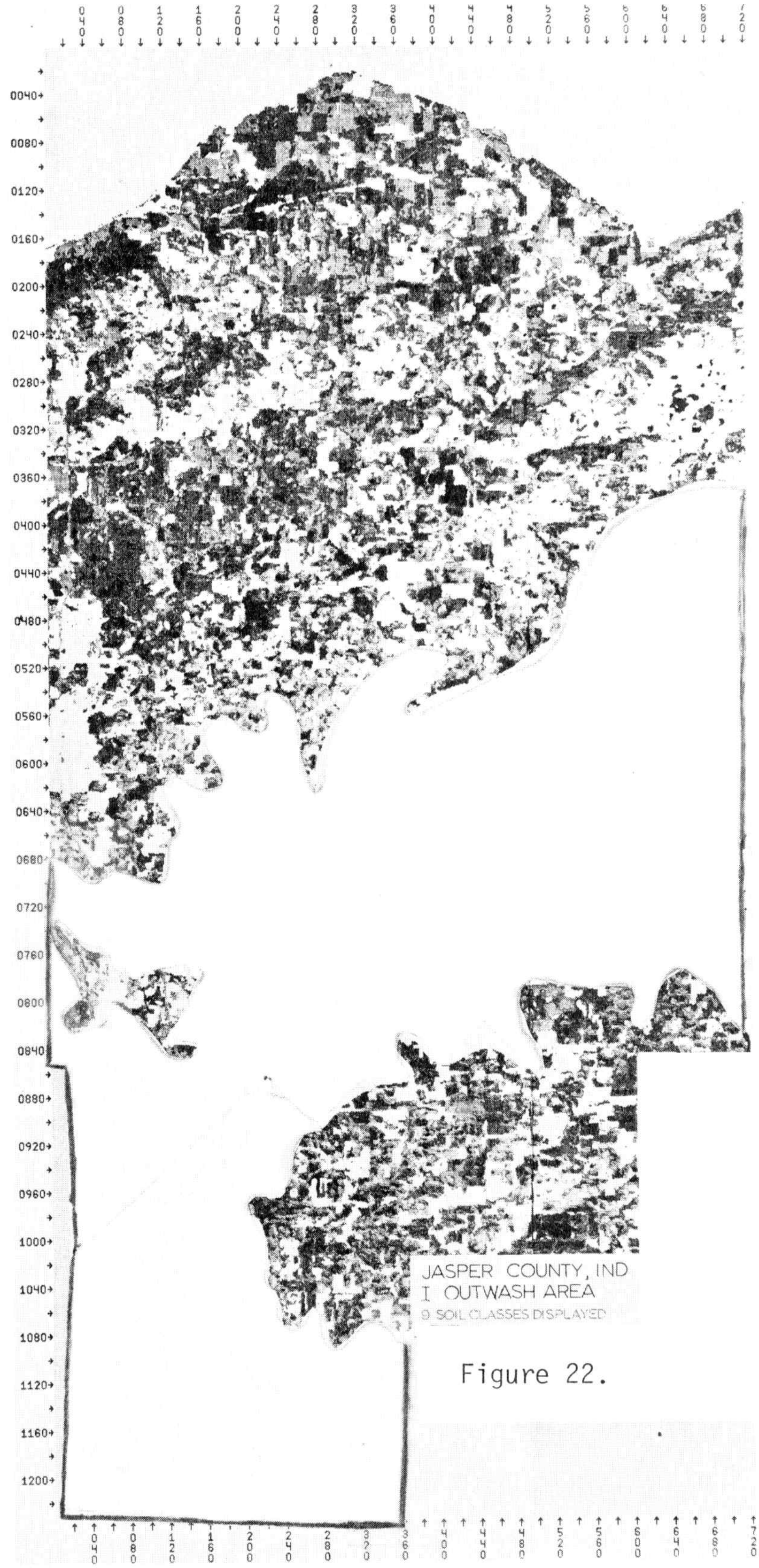

JASPER COUNTY, IND
I OUTWASH AREA
9 SOIL CLASSES DISPLAYED
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Figure 22.

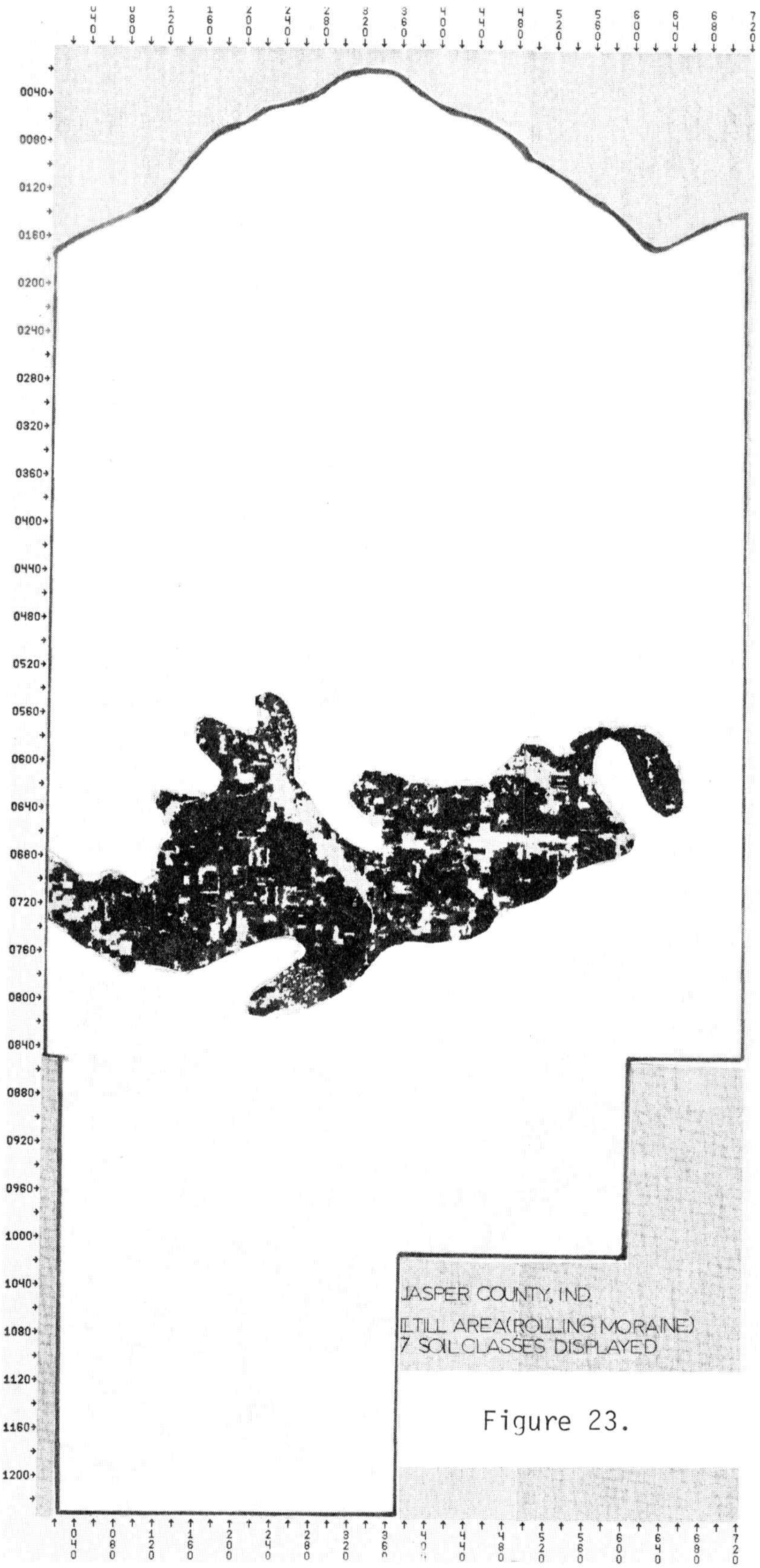
JASPER COUNTY, IND.
II.TILL AREA(ROLLING MORAINE)
7 SOIL CLASSES DISPLAYED
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Figure 23.

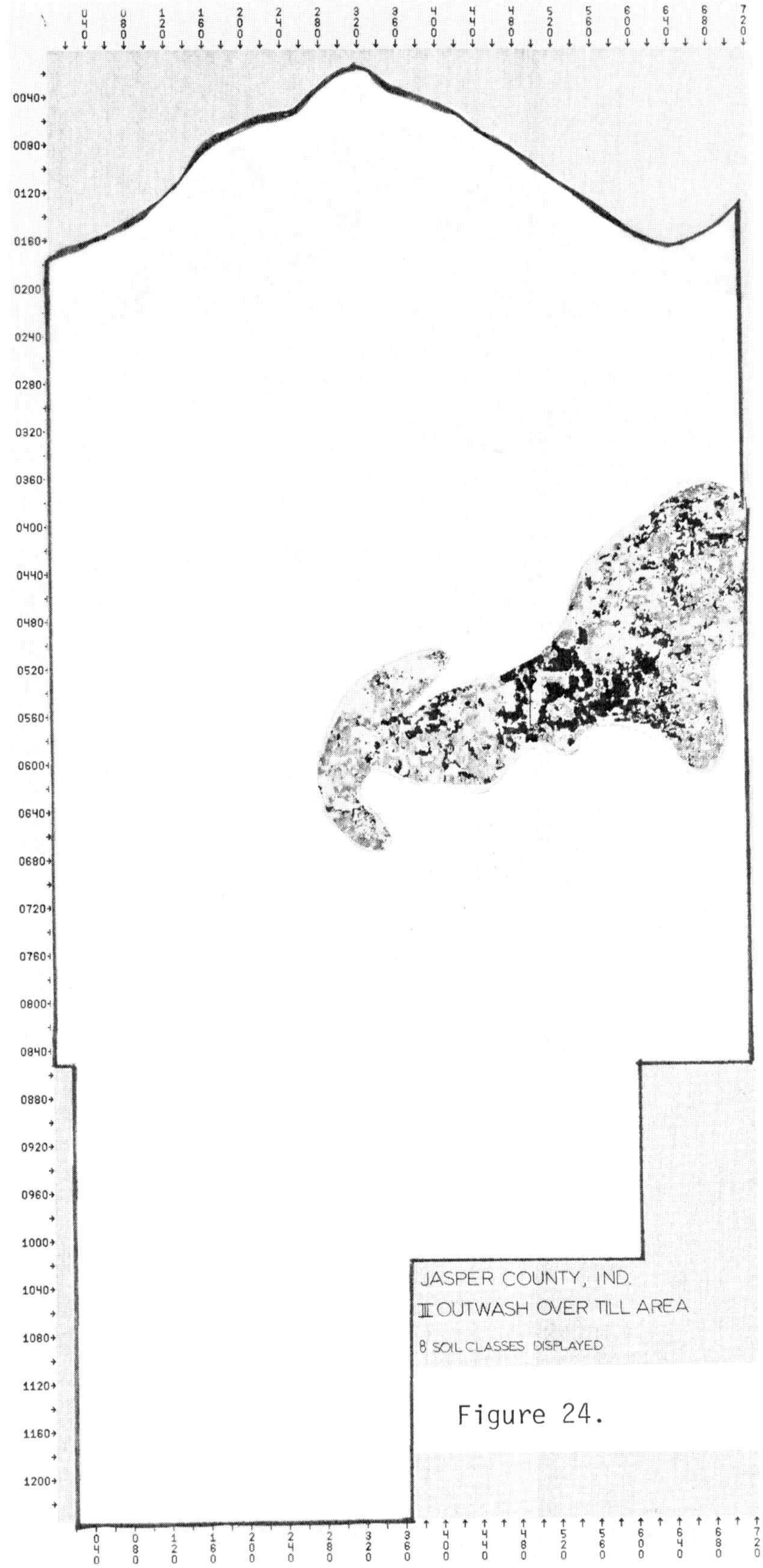
JASPER COUNTY, IND.
III OUTWASH OVER TILL AREA
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Figure 24.

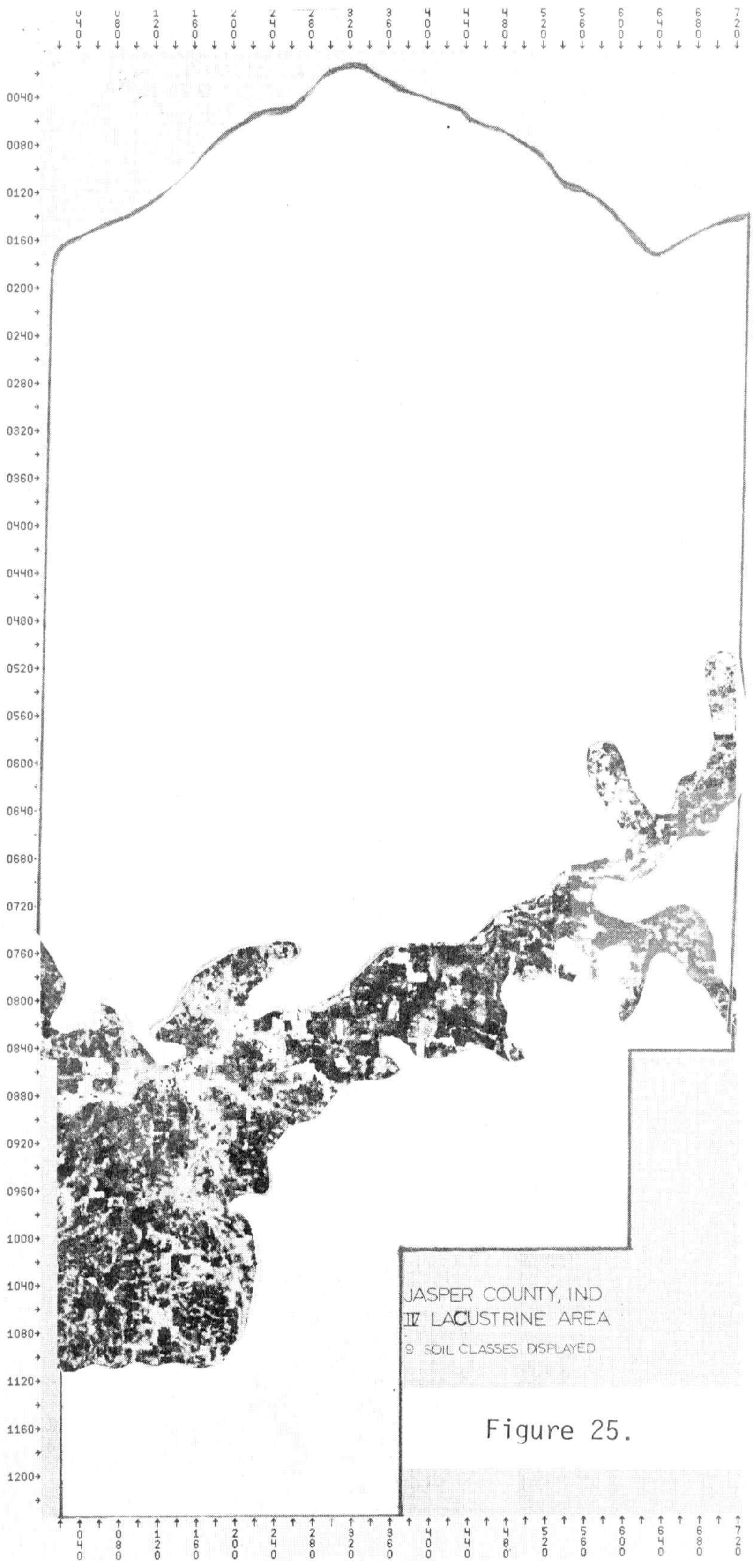
JASPER COUNTY, IND
IV LACUSTRINE AREA
9 SOIL CLASSES DISPLAYED
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Figure 25.

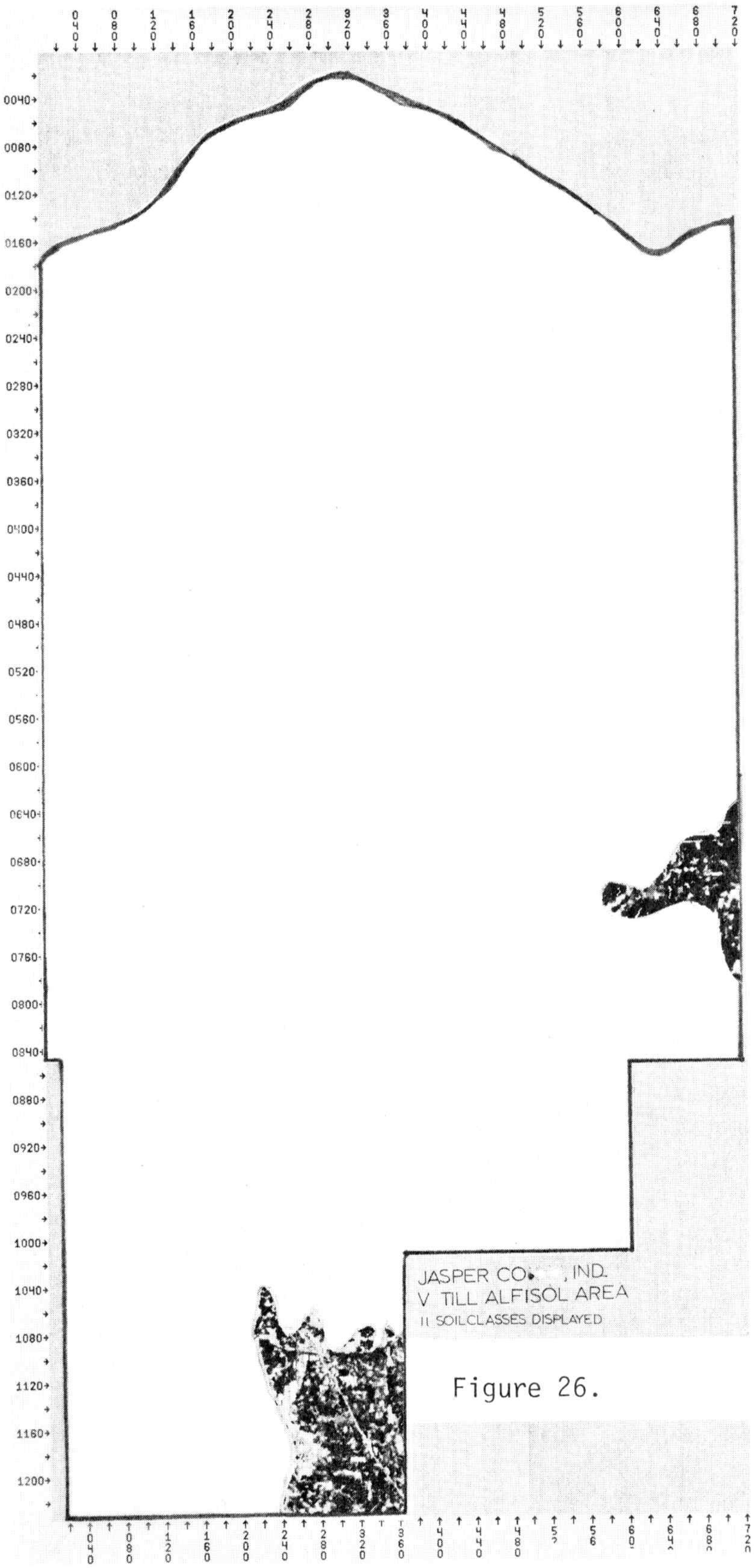
JASPER CO , IND.
V TILL ALFISOL AREA
11 SOILCLASSES DISPLAYED
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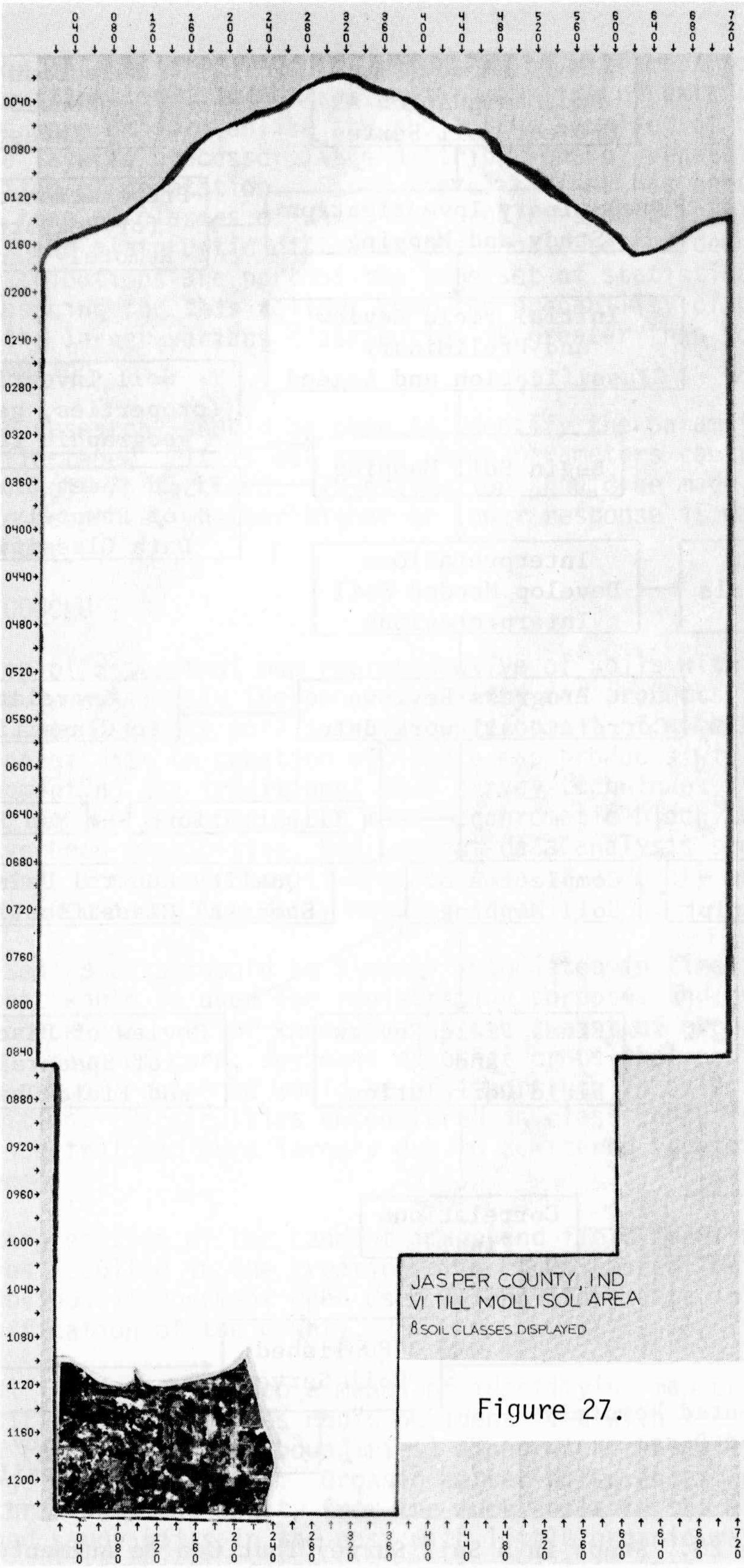
Figure 26.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JASPER COUNTY, IND
VI TILL MOLLISOL AREA
8 SOIL CLASSES DISPLAYED

Figure 27.

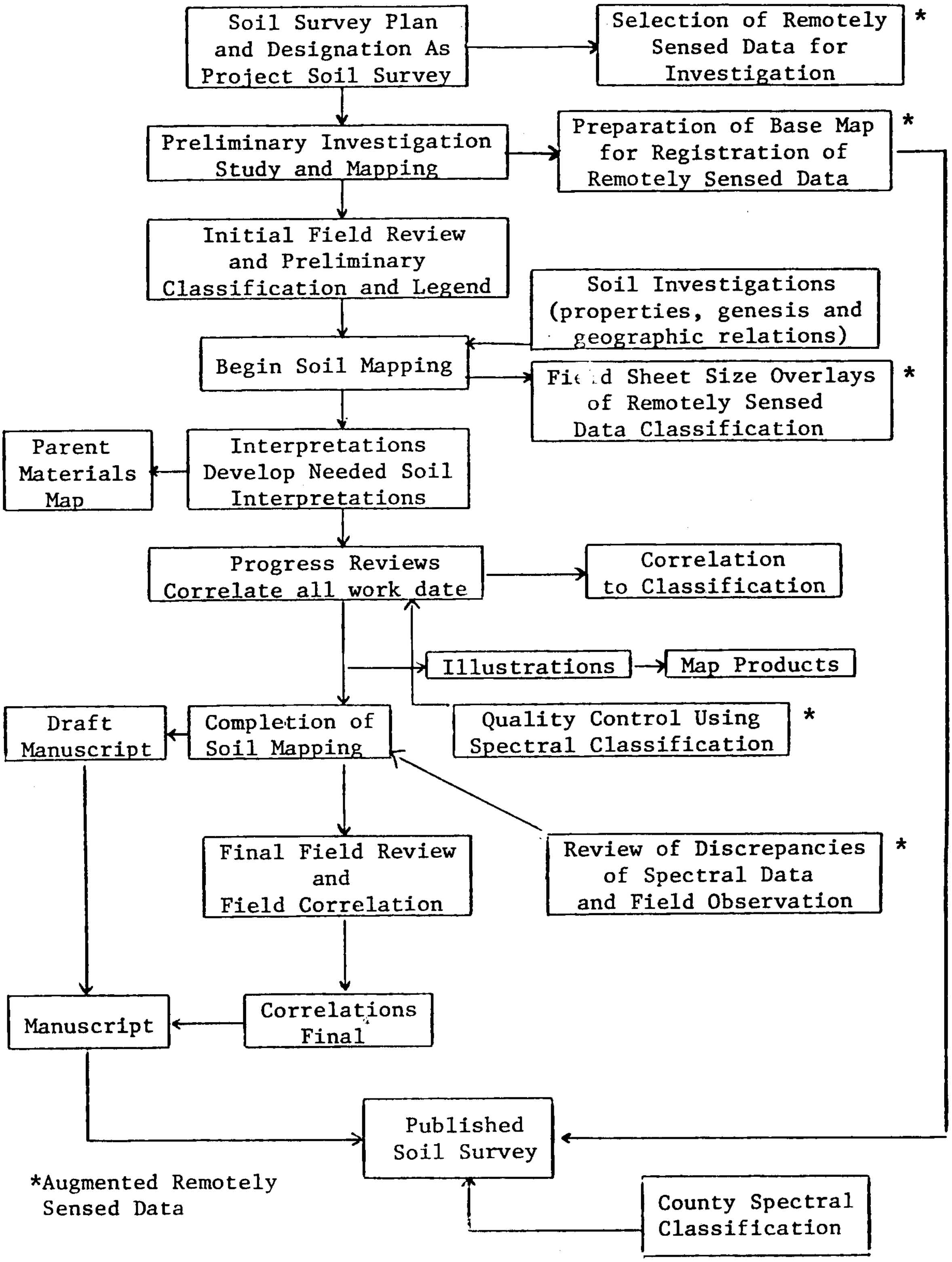

Figure 28. Steps in a Soil Survey That Can Be Augmented by Remotely Sensed Data.

Compilation of statistical distributions is of extreme importance for successful classification. In the systematic sampling of data points, distributions were more uniform unlike the subjective sampling of data points, although in the layered processor large distributions of vegetation weighted the classification of vegetation. Since the classifier has been altered to accept more than 60 classes of data, the problem should be alleviated. Large variances and platokurtic distributions should be avoided when smaller leptokurtic distributions are part of the same set of statistical distributions. The reasoning for this follows that the probability of points being classified in the larger variant distribution is greater than for the smaller variant distribution.

Still more research should be done to identify the parameters that affect soil reflectance. It is not known which parameters contribute the most to overall soil reflectance. Investigation should be made as to how they affect the response, whether higher or lower response is made because of their presence.

SUMMARIES AND CONCLUSIONS

Preparation of a spectral map representative of soils within Jasper County resulted in relatively inexpensive quality map products that could be used in the future county soil survey. Development of a methodology from acquisition of data to creation of usable map products will aid future attempts at augmenting the traditional soil survey techniques. Heretofore, costs in acquiring map products other than panchromatic black and white photography have been prohibitive, but Landsat data analysis should be a reasonable expense for county use if the duration of a county survey could be shortened by increasing the daily mapping capacity.

Remotely sensed data should be closely associated in time to any ancillary data that would be used for registration purposes and/or for correlation (field checking). Prior knowledge of the amount of ground cover type and growth stage of corn, soybeans or other crops that contribute to interference with soil response would be of importance in selecting dates of data acquisition. Difficulties encountered in class confusion in the Jasper County spectral map were largely due to scattered vegetation masking soil responses.

Image interpretation of the Landsat image and field checking of the image boundaries resulted in the creation of a county parent materials map that made an obvious improvement when used as ancillary data in the statistical classification of the county.

All classifications provided a means of identifying map units that could be quantified. Soil series could be identified with the aid of the ancillary data (parent material boundaries) along with the ability to specify drainage characteristics. Organic matter differences were easily identifiable throughout the county from the muck soils in the north and the well drained sandy soils in the east with little organic matter content. Erosion was strikingly separable within the till area. (The other areas have not been checked for an erosion class.)

Difficulties in delineating closely associated soils in some areas were encountered. Somewhat poorly drained soils were confused with moderately well and well drained soils which is not surprising when the closeness of their drainage characteristics is considered. Some classes of somewhat poorly drained soils are so minutely different from better drained soils that discussion as to their delineation can be controversial even upon field inspections. These difficulties must be considered when criticism arises against MSS remotely sensed data being used because of inability to make certain soil delineations.

Evaluation of these classifications indicated the classification involving a systematic data point sampling technique for compilation of training statistics within unique areas to be the most representative. Other classifications that used training samples across the entire county resulted in statistical distributions that were too broad for a fine delineation of spectral responses. Establishing a statistical representation across such a large area as Jasper County created distributions that diminished subtle differences in responses.

The subjective nature of the evaluative techniques was not adequate to evaluate classification performance quantitatively. A homogeneity test was used to determine the necessity of parent material delineation but this also proved inadequate. A more objective approach for determining classification performance and a test less sensitive to point quantities and more sensitive to relationships of distributions are needed.

Random quarter section evaluation was a sufficient means of sampling the county soils, but not all parent materials were sampled. Therefore, questions about the outwash over till area on the last classification remained unanswered. Future classification evaluation should include a larger sampling over a more extensive area.

Initially it was thought that the soil parameter most affecting Landsat spectral responses was drainage characteristics. Results in the outwash area produced spectrally separable soils of the same drainage characteristics indicating that either minor textural or organic matter differences might also significantly affect soil spectral response. Although a successful classification has been produced that will greatly aid Jasper County in their soil survey, more research is needed to determine the soil parameters that make spectral separations possible and to what extent each of the parameters contribute to overall soil response.

Final map products are available that delineate parent materials, vegetation across the entire county, specific sections or any area of the county at any map scale. These map products can be printed on acetate or paper with soil and vegetation classes represented by alphanumeric characters, symbols or varying grey scale values.

Products from this study are to be available along with rectified halftone transparent aerial photographs to be used in mapping the soils of Jasper County. The two images printed at the same scale (1:15840) were specifically designed to be a readily usable tool for field investigations. These products will provide information in areas not readily accessible and can provide the opportunity of extending the mapping time during the summer months when covered crop canopies make it extremely difficult to map.

In conclusion, this research has investigated a number of capabilities using remotely sensed data. Specifically, the research resulted in the following:

1) Designing a methodology for using remotely sensed data from the initiation of a county soil survey to evaluation of the map units;

2) Successfully creating a parent materials map through image interpretation of Landsat data;

3) Analyzing four statistical methods of classifying data points and recommending the most representative of the four to be used in county soil mapping;

4) Finding drainage characteristics, textural and organic matter differences, erosion, and scattered vegetation to be significant contributors to soil responses;

5) Map units that were easily characterized as to their homogeneity, and drainage characteristics in relation to other soils;

6) Readily available single feature maps such as vegetation maps;

7) Definable parent material areas that contribute to a more representative statistical classification of a county soil map;

8) Finding that selection of data acquisition dates is extremely important,

9) Vegetation affecting soil responses across the Landsat channels, however, it was not known how much and to what extent the response was affected,

10) Finding statistical distributions for classification of an area to be of extreme importance if an accurate classification is desirable;

11) Landsat providing a synoptic view of Jasper County that has not been available for other counties unless aerial photographs were mosaiced together;

12) Map products designed to be readily used in the research of county soils.

HOOSIER NATIONAL FOREST PROJECT

INTRODUCTION

Since 1975 the LARS staff have been involved in a demonstration of computer-aided Landsat analysis for the Hoosier National Forest. The demonstration involves the production of maps and tabular acreage statistics for predominant land use on the Brownstown Range District of the Forest. The ultimate objective of this activity has been to define the utility of Landsat remote sensing and computer analysis to day-to-day forest management.

Within the last decade environmental pressures in the form of legislation including the Resources Planning Act, the National Forest Management Act and pending Wilderness Legislation have increased the burden of forest planners to be more responsive to apparent public desires for goods and services from our National Forest lands. The desire to maximize this resource utilization is dependent on timely information regarding the nature of the resource in question. Both man-power ceilings and inflation continue to drive the cost of ground survey, the most common part of forest inventory, upward so that the collection of data from which informative plans can be developed is extremely expensive. Although remote sensing is not capable of providing information regarding all aspects of forest inventory, it can certainly be both timely and valuable at appropriate links in the information chain

Since we have demonstrated the capability of the Landsat technology to provide useful information (described in previous semi-annual reports), we have redefined our thrust to address the form in which that information should be presented. The attached paper, presented before the 1977 American Society of Photogrammetry, details some of the product improvement work in which we have become involved.

THE APPLICATION OF SPATIALLY PROCESSED LANDSAT DATA TO FORESTRY *

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ABSTRACT

The forests and associated range and wildland complexes in the U.S. form an important renewable natural resource base. The management of these resources rely heavily on timely knowledge about their location, condition and status. The gathering of current, accurate information is a prerequisite upon which management decisions will be based. Remote sensing technology offers a vehicle to meet the information needs of resource managers.

However, satellite derived information has not been widely accepted as a resource management tool in forestry. In general, the single tree syndrome has blocked the acceptance of the 1.2 acre resolution capability of digitally processed Landsat data. Ironically, often maps and tabular acreage for forest type and land-use are provided on a 10 or 40 acre cell size. In such circumstances Landsat results provide too much information on a pixel-by-pixel basis.

Improvements in the technology now allow multispectral data to be classified by a new processor which incorporates both spectral and spatial characteristics of the ground cover. Classification unit sizes are variable and can approximate current field mapping unit size. Tabular summaries and maps are provided from Landsat classified data and both can be generated for management classifications. These functions can now help provide information in a form more readily acceptable to the user.

This paper emphasizes new analysis tools available which consider the spatial characteristics of Landsat MSS data. Results and applications of these techniques will be discussed.

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* Paper presented at the 1977 American Society of Photogrammetry Annual Meeting, Washington, D.C.

INTRODUCTION

The environmental 70's will be remembered through history for leaving a telling trail of environmental legislation. The Renewable Resources Planning Act of 1974, and the Forest Management Act and Bureau of Land Management Organic Acts of 1976 will alter and intensify human involvement in environmental concerns. As professionals entrusted with the stewardship of our nation's renewable natural resources, foresters will be under closer scrutiny of the American public Pressures are increasing to provide more goods and services from this diminishing forest resource base. Technologically, we are capable of meeting these demands. If we are fully aware of our resource base, we can positively manage it to provide those services which the public desires. Paramount to meeting these demands is the knowledge of the existing resource potential. Without current quality inventory information, any intensification of management would be fruitless if at all possible.

Wildland and timberland inventories historically have been difficult to obtain because of the complexity of the material being studied and its geographic dispersion and diversity. Since the launch of Landsat we have had the synoptic coverage capable of viewing these resources, and the technical know-how to identify and map their extent. With computer-assisted analysis techniques it appears feasible to reduce large amounts of spectral data to information usable to resource managers. The results presented here describe a demonstration of the potential application of machine-assisted analysis of Landsat MSS data for supplying resource information The study involved personnel from the U.S. Forest Service and the Laboratory for Applications of Remote Sensing (LARS) at Purdue University. The objective of this study was to supply land use classification maps from Landsat for the Brownstown Ranger District, an area that the Forest Service had recently mapped. The resulting maps and tabular data from both processes would be compared and the potential of machine-processed Landsat data evaluated.

METHODS AND MATERIALS

The test site (Figure 1) is a continuous block of 56,680 hectares (140,000 acres), situated in south-central Indiana. The area is located on Illinois aged topography and consists of numerous northeast trending ridges and valleys The predominant vegetation is the oak-hickory association, common to the central hardwood region of the Eastern United States. In addition to producing timber, the area has heavy recreational pressures due to its proximity to some large population centers.

The Forest Supervisor's Office was in the process of updating their area management plans and had just completed a land use map of the site. The map was comprised of seven classes (hardwoods, conifers, brush, crop, pasture, water and urban) and was developed through photo-interpretation and ground survey. The minimum area displayed on the map was 85 hectares (21 acres), or one hectare more than the mid-point of the mapping unit size, which was 16.19 hectares (40 acres).

We were to attempt duplicating the Forest Service map using the Landsat data. The analyst used a "modified cluster" technique for selected training areas. Spectral classes were identified with the aid of small-scale color infrared photography. Spectral groups were combined during the classification to match the land use classes identified by the Forest Supervisor's staff. The final map contained only five classes: hardwoods, conifer, brush, ag lands, and water. The urban class was dropped since there were virtually no identifiable urban areas on the site. Crop and pasture lands were combined into an agriculture class because they were difficult to separate on the date of the data used. The final map was prepared at maximum Landsat resolution so that mapping unit size equaled resolution, or approximately 0.45 hectares (1.1 acres).

RESULTS

The first map that we produced was the per-point classification, Figures 2a and b, which visually agrees with the Forest Service map. However, a number of points appear to be misclassified which cause a "salt and pepper" pattern on the map. This, in fact, might be a true representation of the spectral canopy of the forest. Undoubtedly, there are a few points which are misclassified. This is probably due to the fact that the spectral definition of one of the classes is too broad. For example, there were few brushland training classes so the variance of that class may be expected to be greater than say the variance of the deciduous forest class. The deciduous forest class was formed by grouping various spectral classes which we identified according to different slope, aspect, and crown closure density situations. What has apparently happened is that one of the low crown density subgroups has been confused with brushland. Once the reason for the misclassification is understood, the analyst can reselect specific training areas, thereby trying to reduce the variance in each class's mean. By so doing, the confusion between the sparse or less dense deciduous and brushland will be reduced and the classification map will improve. This process can be both time consuming and costly depending on the amount of "cleaning" that is necessary.

At maximum resolution the Landsat classification map is visually unappealing and does not correspond well to the forest map. The problem was that we were comparing a map where each unit represents 0.45 hectares with a map where the smallest unit is 8.5 hectares (21 acres).

To make the comparison meaningful, we had to bring the mapping units into closer agreement. Our next map (Figure 3) was prepared by eliminating every other line and column. Each element on the map now represents a ground area of approximately 2.02 hectares (5 acres). The data are not averaged in this process, just simply eliminated. Obviously, this approach is satisfactory in some situations, although increasing the frequency which one drops lines and columns is not suggested.

DISCUSSION

The material provided to the Forest Supervisor was useful but not optimal for his specific situation For this project we had to consider more than the spectral characteristics of the scene. Somehow, we had to account for the spatial variations in the forest canopy. In actuality, the photo-interpreter accounts more for textural repetitions in the scene than tonal associations.

During the first decade of research and development in applying digital analysis techniques to multispectral remote sensing data, emphasis has been concentrated on extracting information from the spectral domain. In other words, the methods applied have been those which analyze the spectral measurements on a pixel-by-pixel basis. Some work has been done to utilize temporal information by registration and analysis of data from the same scene collected at different times. Even less work has been done in extraction and use of spatial information based on shape, context, texture and other forms of spatial relationships which, from photo-interpretation experience, are known to be significant

An algorithm has been developed which incorporates the simple spatial relationship-adjacency into the machine analysis process. The processor called ECHO, for Extraction and Classification of Homogeneous Objects, allows the analyst to account for the textural qualities of the data during classification.

Flexibility is provided to allow the user some latitude in matching the data set to the objectives of the analysis. This control is achieved through parameters which determine: (1) the cell size or number of pixels comprising the basic classification unit, (2) the level of homogeneity required within a cell, and (3) the degree of annexation of similar cells into aggregate fields. The cell size used is dependent on the resolution of the sensor and the area of the "ground object" which is to be detected. The homogeneity parameter controls the classification of the cell and ranges from a per-point classification of each pixel to complete per-field classification where each cell is treated as a unit. The third parameter controls the degree of annexation of cells of similar spectral properties into larger aggregate fields.

With the ECHO processor we reclassified the data utilizing various cell widths. To illustrate, we selected a six-section area in the northern part of the site. As we will see, in Figures 4 through 6 the map becomes more blocky as cell width is increased. With careful selection of the classification parameters, the analyst can control the amount of cell splitting that the classifier performs. Cell splitting allows for a class of high variance to be distinguished from surrounding material. The option would be useful in separating small inclusions of pine plantations from the more predominant surrounding hardwoods. The hardwood class contains a greater spread, or variance, than the conifers, thereby allowing for the separation between the classes.

When carefully applying the ECHO processor, we can eliminate small errors which often appear to be areas of misclassification. This, therefore, makes the final map more appealing to managers who are used to maps possessing less detail. Additionally, a slight improvement in classification accuracy is also sometimes achieved. Again, this is due primarily to combining pixels which occur at the tail of a class distribution and are prone to misclassification because they are placed into a class with greater variance.

CONCLUSIONS

Spatial processing has a definite place in the analysis of Landsat data for renewable resource management. For large regional mapping projects, Landsat data are apparently more sensitive to changes in the ground scene than necessary. The ECHO processor accounts for the spatial variability in the scene. Maps can be produced which more closely approximate the user's state-or-the-art of current need.

There are other approaches which can be utilized. We have only considered a processor which accounts for the primary characteristic of spatial information--class variability. This may, in fact, simulate the thought process which an interpreter uses in aggregating classes into cells but does not replicate the physical process. In actuality, an algorithm which determines the majority class within a cell and classifies the cell by the majority would more closely approximate an interpreter's physical process. We intend to look at this approach for future work.

During this study we identified an apparent non sequitur. The apparent paradox is simply stated:

> Because of geographic diversity and the physical difficulty and cost involved in collecting natural resource data, Landsat would appear to have obvious application. Resource managers, however, are concerned because the resolution of the satellite data is less than considered optimal at 0.45 hectares (1.1 acres). However, these same individuals produce maps and tables at 16 hectares (40 acres) or larger cell sizes to assist in development of large area plans.

As scientists have been too willing to sell resource managers too much based only on a system capable of providing spectral information, users have been too concerned about replacing existing aerial (photo-interpretation) data collection and analysis systems. Much discussion has revolved about the large area implications of Landsat and computer-aided analysis but ignored the salient features, such as spatial manipulation of the data, that would make it more appealing.

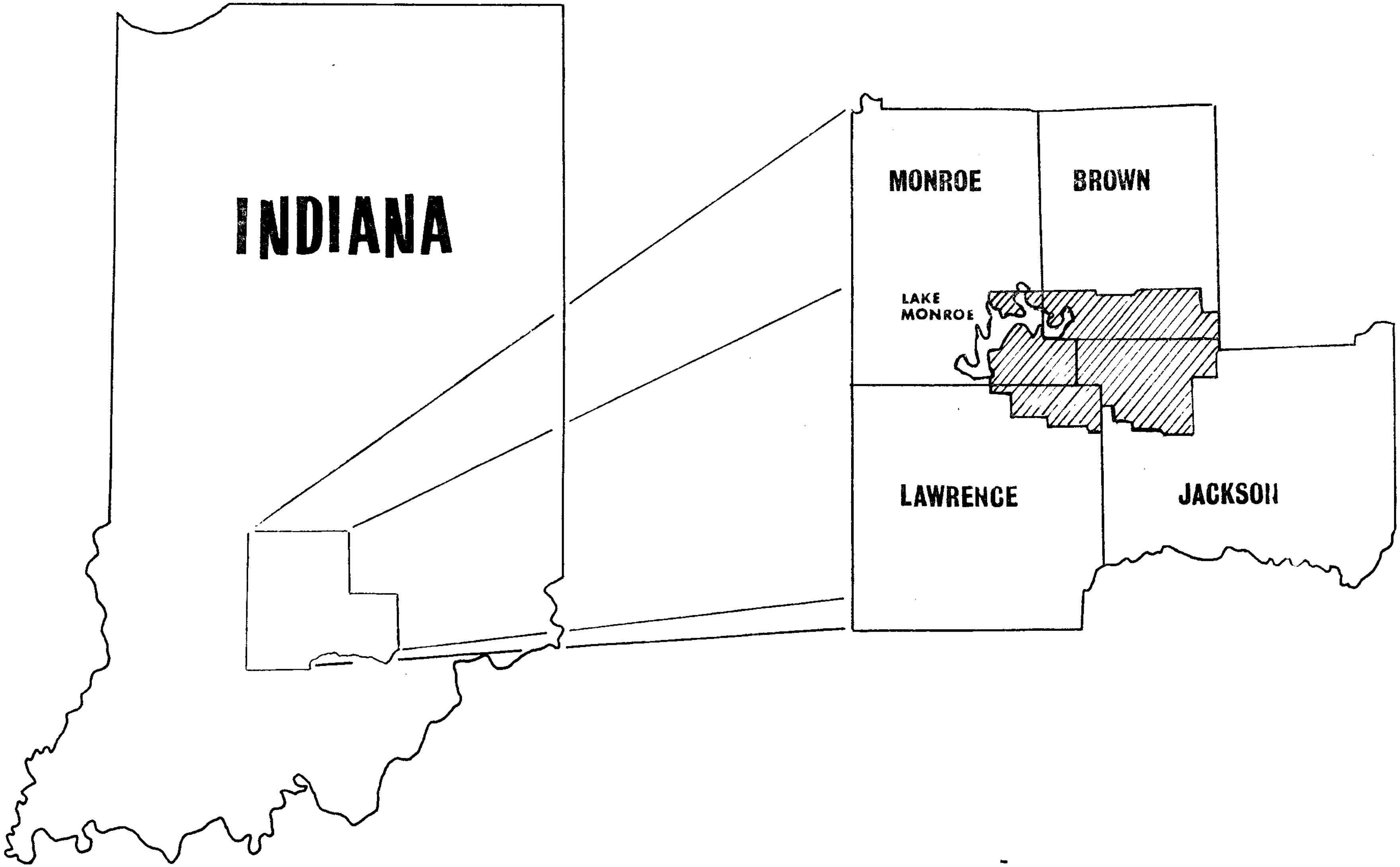

Figure 1. Hoosier National Forest test area in South Central Indiana.

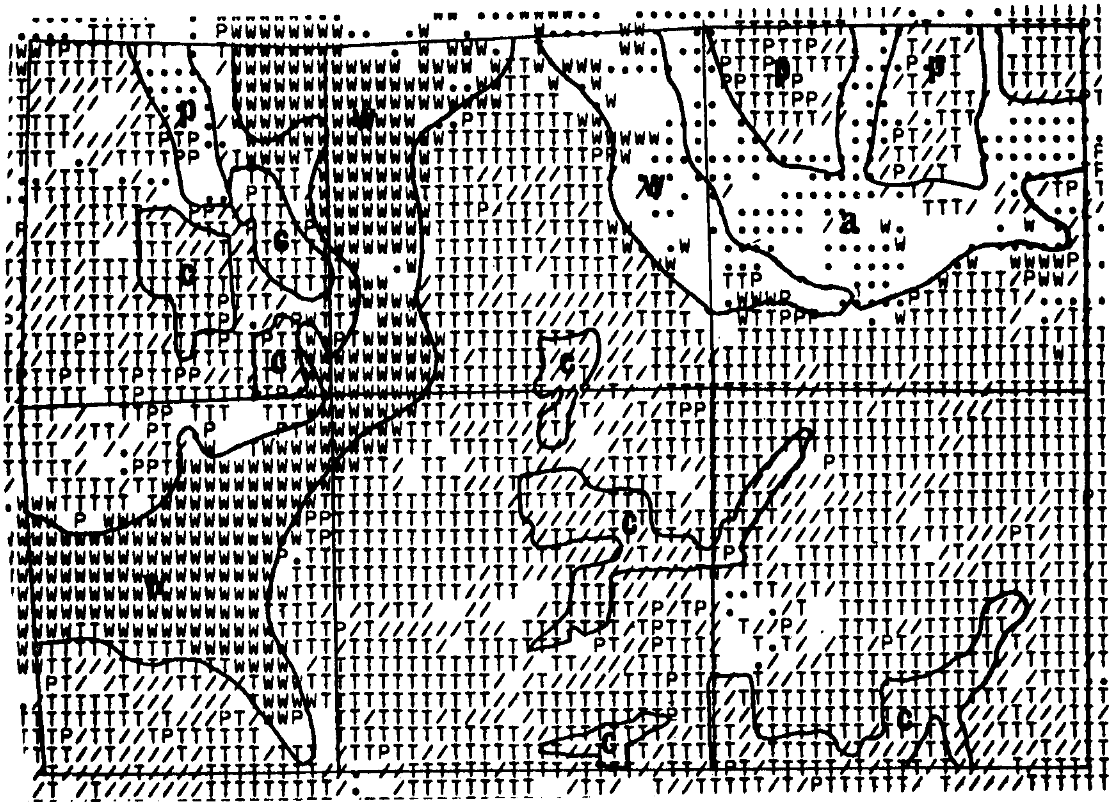

Figure 2a. Per-point classification of six sections in T7N, R2E. Symbols T/P = Forest, Blank = agland, • = Pasture, and W = Water.

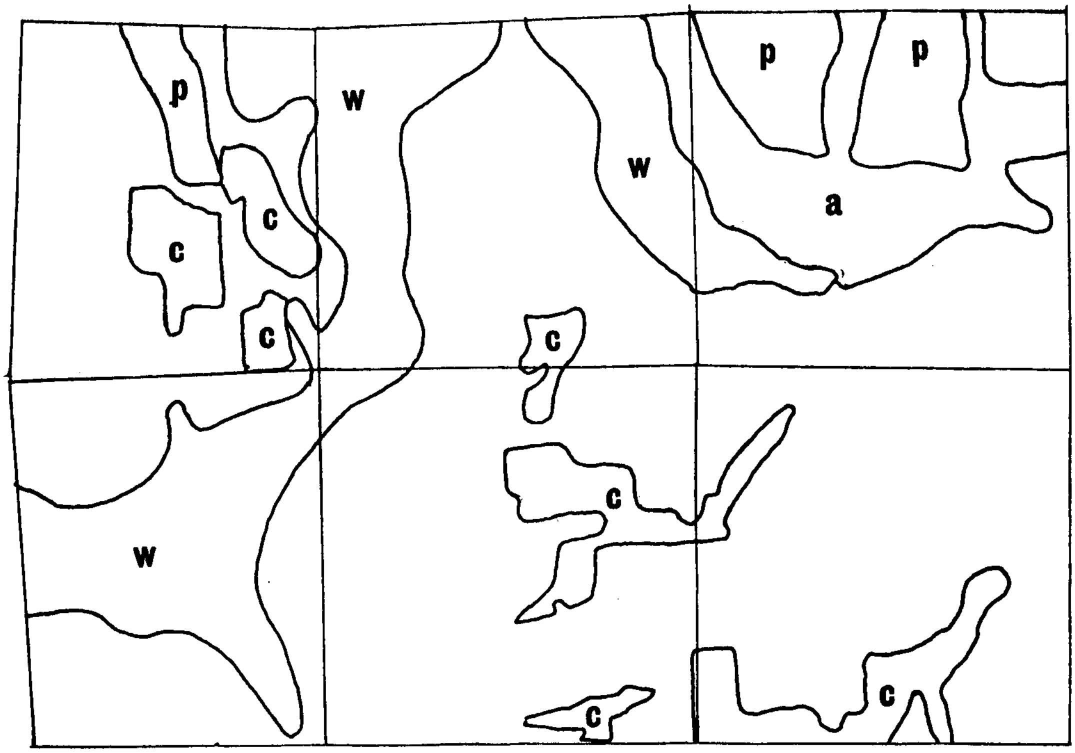

Figure 2b. Simplified Forest Service type map for the same area as classified above. Blank = forest, C = conifer, a = ag lands, P = pasture, and W = water.

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Figure 3. Classification of six section area where every other line and column were dropped in order to simulate a 2.02 hectare mapping unit.

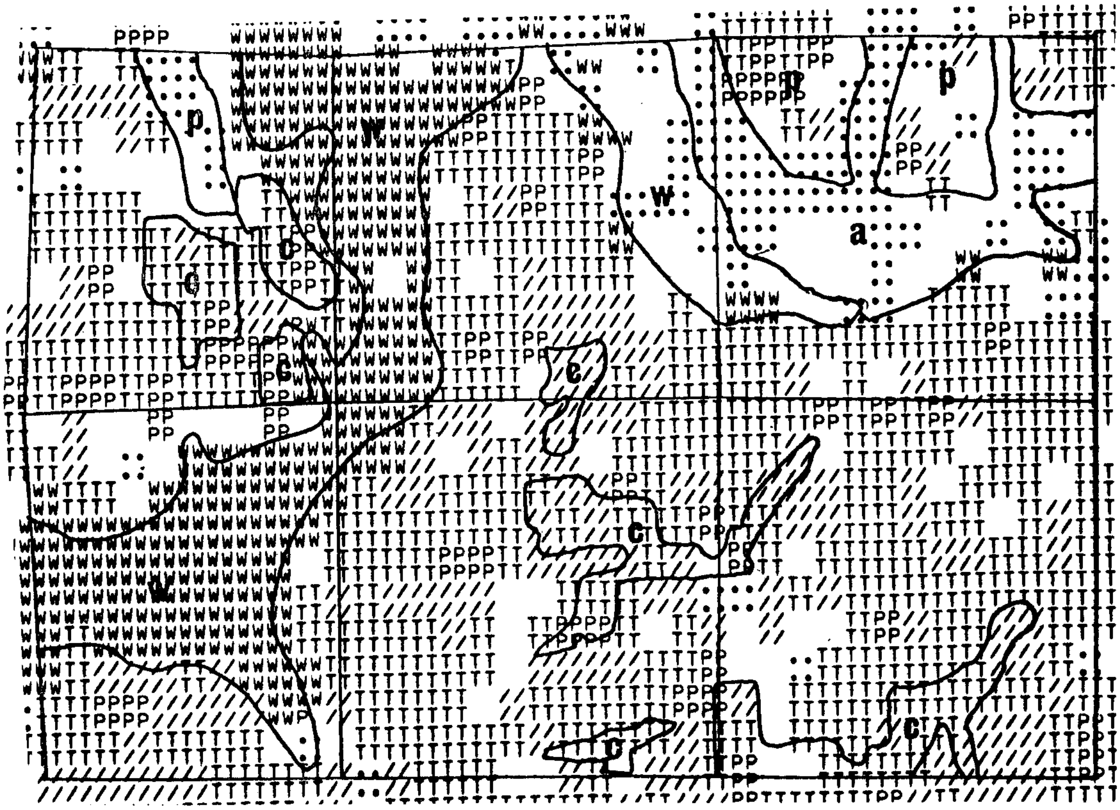

Figure 4. An ECHO 2 x 2 cell classification.

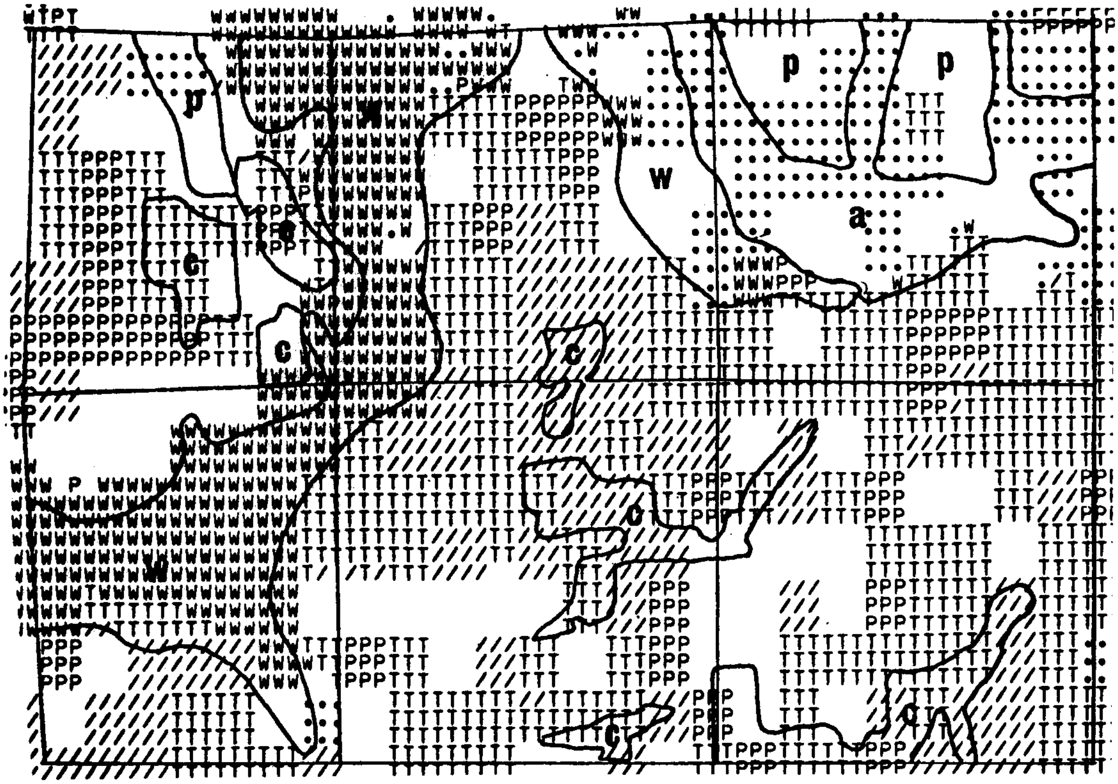

Figure 5. An ECHO 3 x 3 cell classification. Note the blocky appearance of the map.

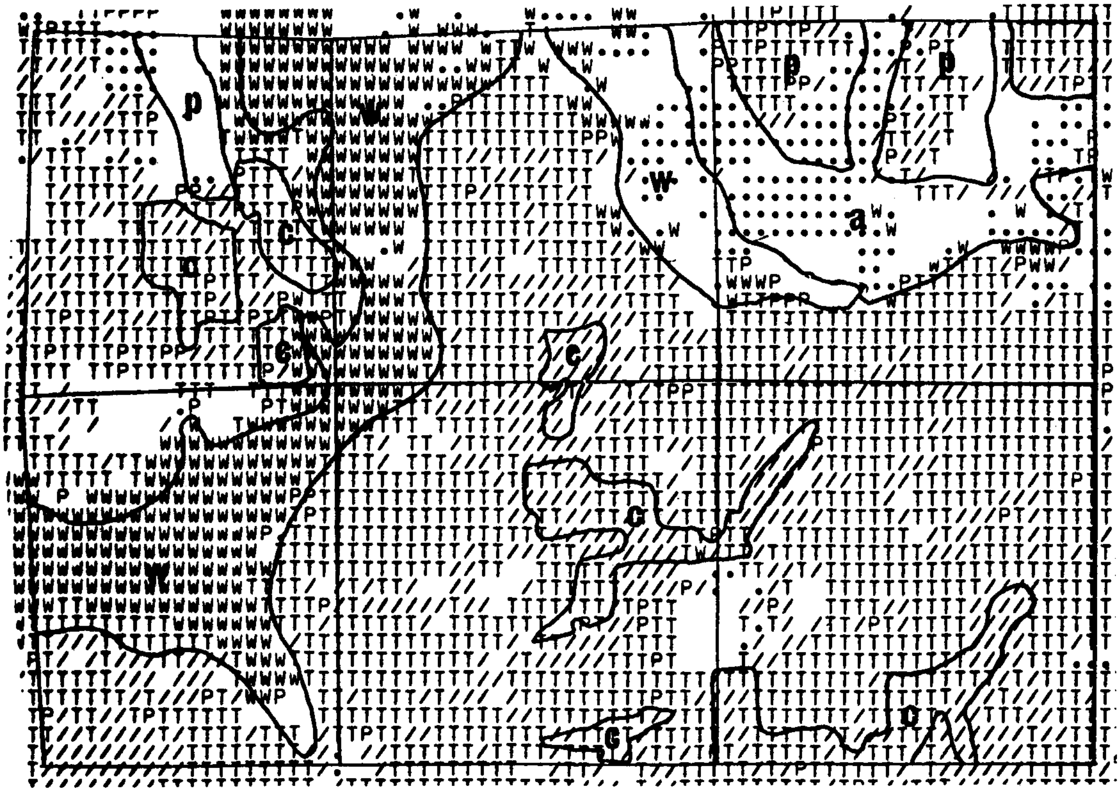

Figure 6. An ECHO 4 x 4 classification. Some of the blocky appearance has been removed by allowing cell splitting.

HEAT LOSS DETERMINATION IN RESIDENTIAL BUILDINGS

INTRODUCTION

Thermal Remote Sensing (or Thermography) can be defined as a technique of imaging an object using the thermal infrared energy radiating from the surface of the object. The instrumentation consists of a thermal scanner and one or more monitors to display the area being scanned. Thermography has been developed as a tool to measure the temperature of various surfaces. The non-contact nature of this method, together with the display of the entire surface-temperature distribution over an object, gives thermography unique application possibilities. These include medical diagnosis (cancer detection, etc.), hot spot detection in electrical power transmission lines, surveys of land and sea temperatures from aircraft and satellite, non-destructive testing (NDT) of products for flaws, and biological studies of plant development and insect physiology.

In recent years, energy being the focus of attention, new applications of thermography for energy conservation have emerged, particularly in the industrial sector. A survey of the literature indicates that most of the work so far has been more qualitative than quantitative. The qualitative analysis of thermal images (thermographs) reveals "apparent" areas of heat loss (hot spots), giving no indication as to how much heat is being lost. This study investigates the feasibility of extracting quantitative heat loss information through the computer-aided analysis of thermal imagery.

OBJECTIVES

The project objectives are:

1. To assess the value of building heat loss data to municipal government community development activities.
2. To develop a mobile thermography unit capable of making radiant temperature surveys of building side walls.
3. To assess the feasibility of developing a computer-aided analysis system extracting accurate economic information regarding energy losses in building side walls from calibrated digital thermography data.

STATUS

The Community Development Agency for the city of West Lafayette provided a list of residences available for conducting the heat loss survey. It was originally intended to collect thermal data from several homes varying in age, building materials and the amount of insulation. However, due to technical problems and lack of ideal weather conditions (cold, calm, clear nights), data were collected from only two houses. Using a DYNARAD model 209A IR scanner, thermal imagery was obtained and recorded on videotape. A total of 10 images of the side walls of the two houses were recorded, 6 from the first house and 4 from the second. Ancillary data collected consisted of: photographs of the houses, ambient temperature measurements inside and outside the houses, and some radiant temperature readings of "critical" points within each scene using a BARNES PRT-5 radiation thermometer. These readings served as reference temperatures later on in the analysis. The images were then digitized, using an analog to digital converter developed at LARS, and reformatted into LARSYS multispectral storage tape format, compatible with LARSYS functions. The thermal imaging system is illustrated in Figures 1 and 2. The six images from house 1 were calibrated using a two-point linear calibration. Temperature distribution maps (T-maps), which are grey scale printouts indicating grey level (response)-temperature associations, were generated (Figure 3).

These temperatures are not true but "apparent" temperatures as no correction has yet been applied for emissivity. A computer program is being developed which will perform the emissivity correction, given the spectral emissivities of the building materials contained in the scene. A literature search conducted to obtain the spectral emissivities (in the 8-14μm region) of building materials has revealed a dearth of such information.

The next phase of the project is to generate a data channel containing the digitized boundaries of the different building materials in the scene along with total emissivity (due to lack of spectral emissivities) information for each material. This additional channel of data will be used in making the emissivity corrections to yield the true temperature distributions in the scene. Once the true temperatures and the ambient temperatures are known, heat transfer equations can be applied to extract quantitative heat loss information.

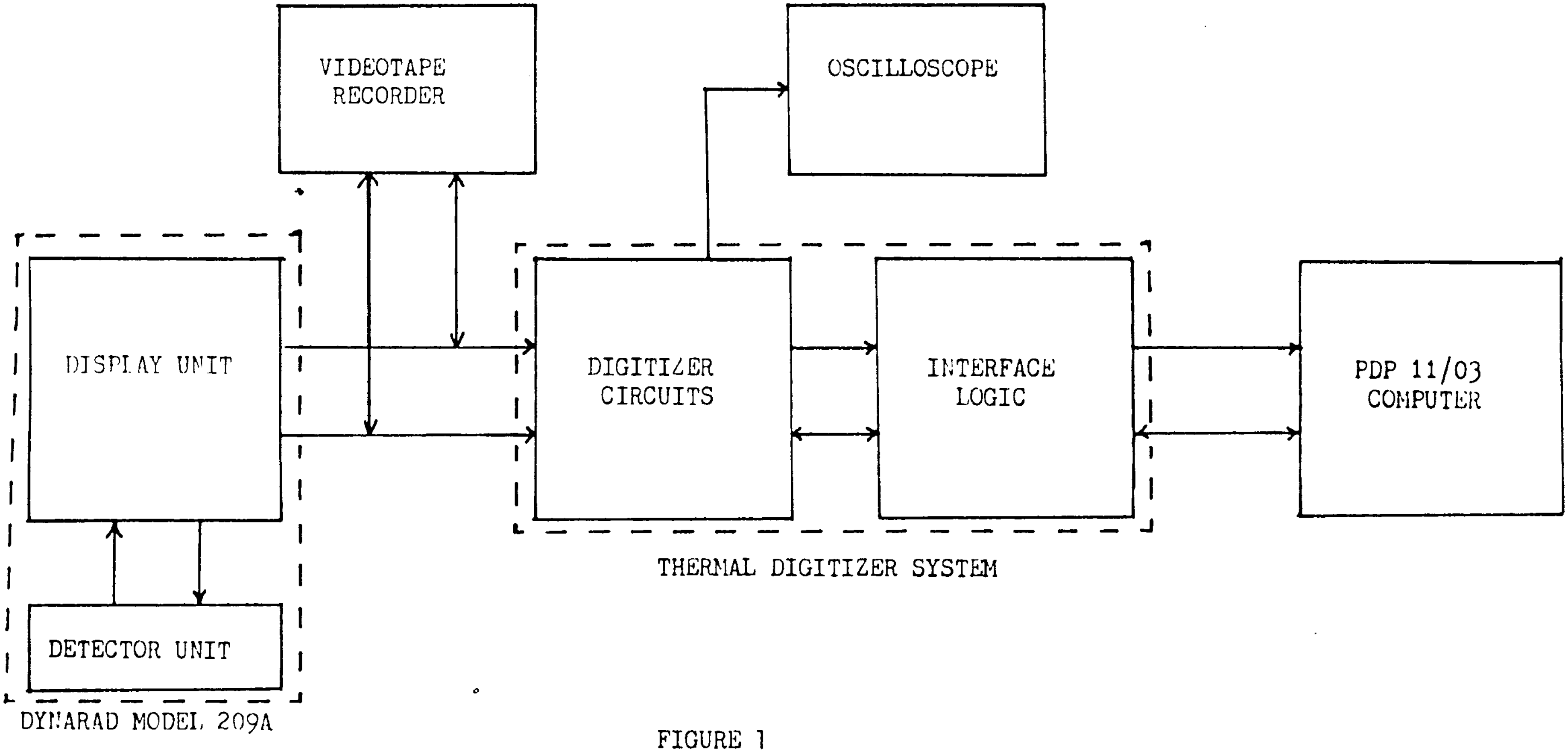

FIGURE 1

THERMAL IMAGING SYSTEM

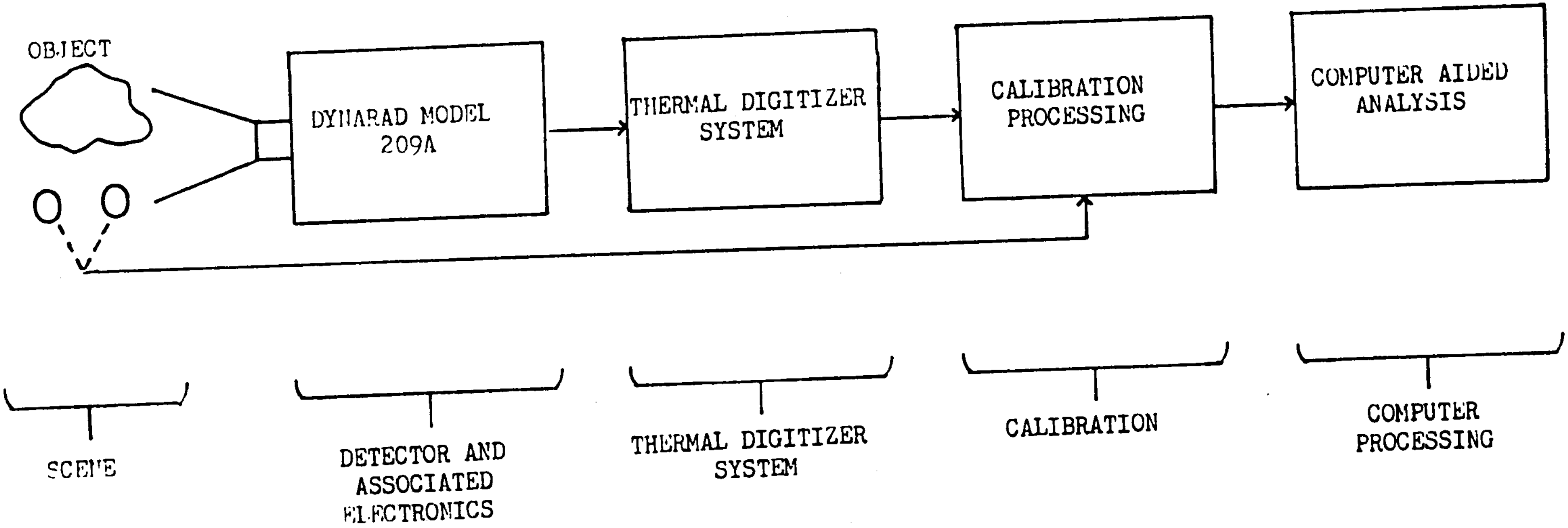

FIGURE 2

CONCEPTUAL BLOCK DESCRIPTION OF THERMAL IMAGING SYSTEM

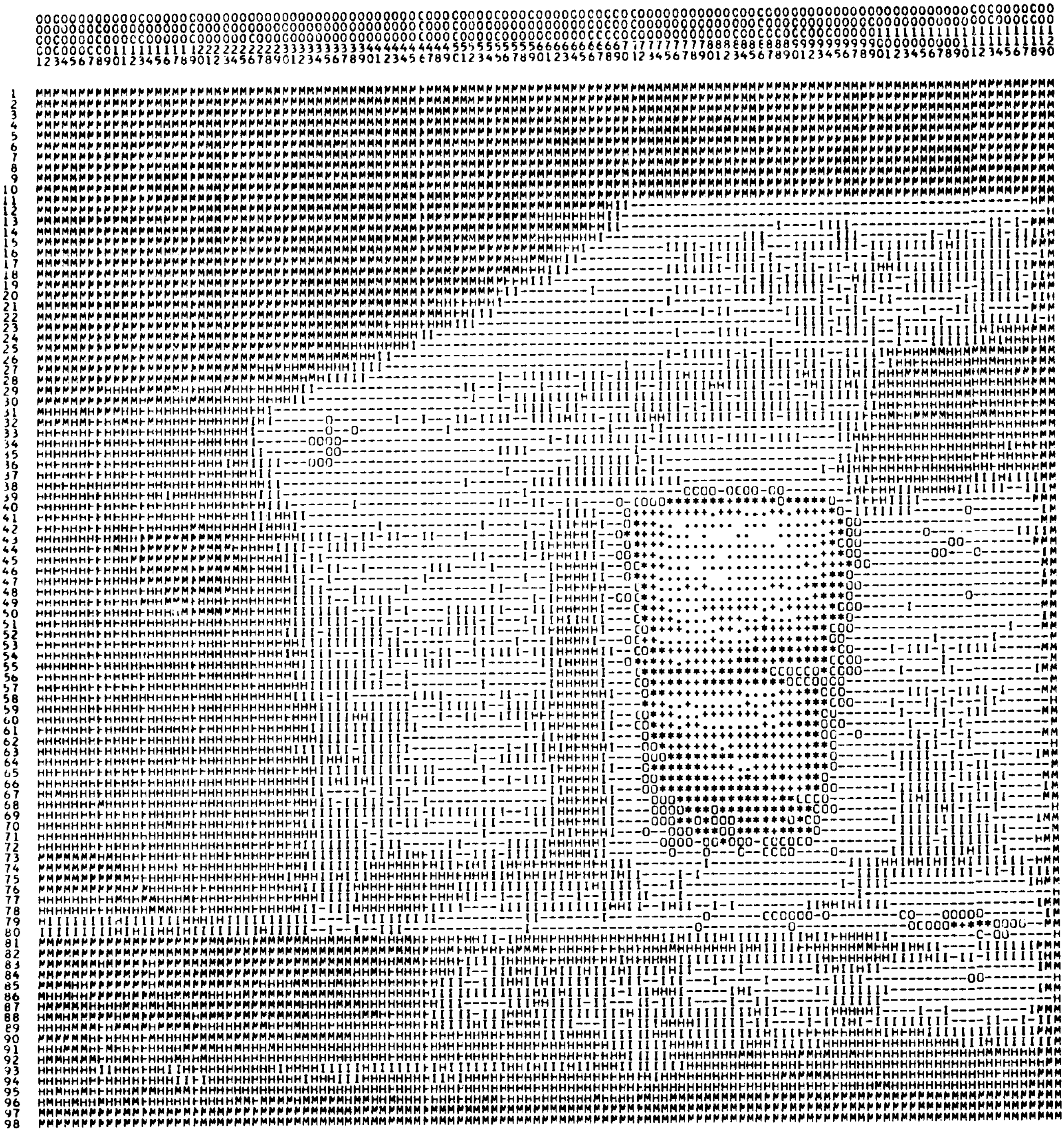

Figure 3. Temperature distribution-association map.