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Automatic Interpretation of Terrain Features

The use of multichannel imagery offers the greatest potential.

INTRODUCTION

THE identification of terrain features is based on the interpretation of the elements of topography, drainage, erosion, tone, vegetation and culture. The terrain features of interest might include the identification of the basic land forms, or features within a land form, such as soil composition, moisture conditions, and vegetative cover. The identification of these features in the past was based largely on the qualitative evaluation of aerial photography in conjunction with limited field checking. With the availability of new sensors (e.g., radar, infrared, multichannel, multilens) the amount of information obtained and the accuracy of interpretation of terrain features have increased. The speed with which multiple film types, multiband, and multisensor data are acquired and the increase in the amount of data to be analyzed are rapidly exceeding the interpretation capabilities of present methods for analyzing and integrating the information content. As more and more researchers are investigating information collected by these forms of data gathering systems, it has become increasingly evident that in order to handle this mass of data, there is a need for developing some method for automatically analyzing the aerial photography and imagery.

ABSTRACT: *The identification of terrain features is based on the interpretation of the elements of form and the elements of tone and texture. Measurements of the element of tone and texture were performed with a densitometer adapted to obtain continuous scans. Some of the factors investigated included: (1) effect of film types and filters; (2) seasonal effects; (3) aperture size; and (4) scale. Measurements were also performed on multichannel imagery (ultraviolet through far infrared) and spectral response signatures were developed for various target materials. A technique was also developed for the preparation of isochromal maps (maps showing uniform color zones) from densitometric scans on color photography. Efforts to develop diagnostic patterns for various terrain features from measurements on a single film type were not successful. Analysis of the spectral response curves developed from multichannel imagery indicated that this approach offered the greatest potential for delineating terrain features. The technique developed for isochromal mapping offers a method for automatically mapping various tonal patterns present on color photography. This has immediate application for the identification of those terrain features which are directly related to color tonal patterns.*

The tonal pattern is one of the major elements in identifying many terrain features and the initial efforts of the research project reported here were directed toward quantitizing the element of tone. The research was

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* Submitted under the title "Investigations into Automatic Interpretation of Terrain Features."

performed as part of a project at Purdue University on the evaluation of remote sensor systems for identifying various terrain conditions.[1] Aerial photographic coverage for the project included a total of nine aerial flight missions flown over three controlled test sites during the period May 1965 to June 1966. Coverage included: (1) various aerial films—natural color, color infrared, color negative, black-and-white panchromatic, and black-and-white infrared; (2) a multiband camera—9 lens; (3) radar sensors—K-band; (4) infrared sensors—4.5–5.5μ and 8–14μ bands; and (5) a multichannel sensor—simultaneous coverage of ultraviolet through far infrared. Not all combinations were obtained in any one flight program; however, several combinations were obtained during each flight so that sufficient comparisons could be made.

STUDY APPROACH

Three main approaches were attempted in investigating the possibilities of quantitizing the element of tone and developing diagnostic patterns for various terrain features. These included:

1. Performance of continuous densitometric scans to determine whether typical tonal signatures existed for various terrain features;
2. Preparation of "isotonal" (regions of uniform film densities) and "isochromal" (regions of uniform color tone) maps to determine if similar terrain features could be delineated based on differences in their density patterns or color patterns; and
3. Development of normalized spectral response signatures from the multichannel imagery to determine if particular regions of the spectrum were especially useful to differentiate between various terrain features.

EQUIPMENT AND SCANNING TECHNIQUES

Two densitometers were used in the study. A reflection densitometer was used to obtain density readings from prints and a transmission densitometer was used to obtain density readings from transparencies and negatives. Both densitometers contained four filters: visual, red, blue and green. The output from the densitometers was connected to a chart recorder that included an adjustable span, adjustable zero and a six-speed chart selector.

Both of the densitometers used were point measuring instruments; therefore, a technique was developed to obtain continuous scans. The technique consisted of: (1) mounting the photograph in a predetermined position so that a particular line was scanned; and (2) manually pulling the density head across the photograph in the case of the reflection densitometer, or pulling the film holder under the density head in the case of the transmission densitometer, at a constant rate. The rate used in most scans was one inch every ten seconds. The recorder chart speed was set at the same speed as the scanning rate so that one inch on the chart would equal one inch on the photograph. A stop watch was used so that the operator could continuously check his progress.

Although these techniques were subject to inaccuracies in determining the exact positioning of an object, good results were obtained by these methods. Four different operators were trained in a relatively short time and could obtain satisfactory results. The main problem was the difficulty in maintaining constant speed throughout the scan. Where accuracy is desired, a device could be constructed to give constant scanning rates or an automatic scanning microdensitometer could be used.

A variation of this technique was used when it was desired to compare the amount of detail obtained over a given line at different scales of photography. In this evaluation, the chart speed and rate of scan were adjusted for each scale of photography so that the final length of the scan line was the same in each case.

RESULTS AND ANALYSIS OF DATA

CONTINUOUS DENSITOMETRIC SCANS

Continuous density scans were performed over a variety of terrain features on individual photographs and on uncontrolled mosaic strips to determine whether typical reflection densitometric patterns could be obtained. The influence of various parameters on the tonal patterns or on the density scans obtained were investigated. The parameters investigated included: (1) differences due to film types; (2) differences due to type of filter utilized for scanning; (3) season of the photography; (4) aperture size of densitometer; and (5) scale of photography.

A test strip, containing a variety of surface conditions, was selected for evaluation of the parameters. The test strip is shown in Figure 1. The dotted white bands indicate the lines scanned on the various film types. The middle band, scan 2, was used for detailed comparisons. The reference points on scan 2 refer to the features compared on the various scans. These reference points were used in all comparisons except for the comparison on the influence of scale on the scan pattern. A different test strip was used for that analysis.

Comparisons in many cases had to be made between scans obtained on the reflection den-

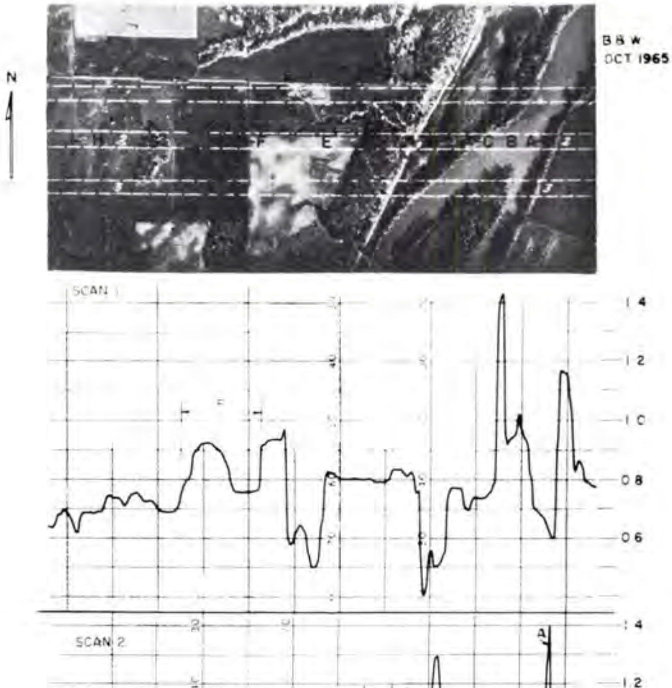
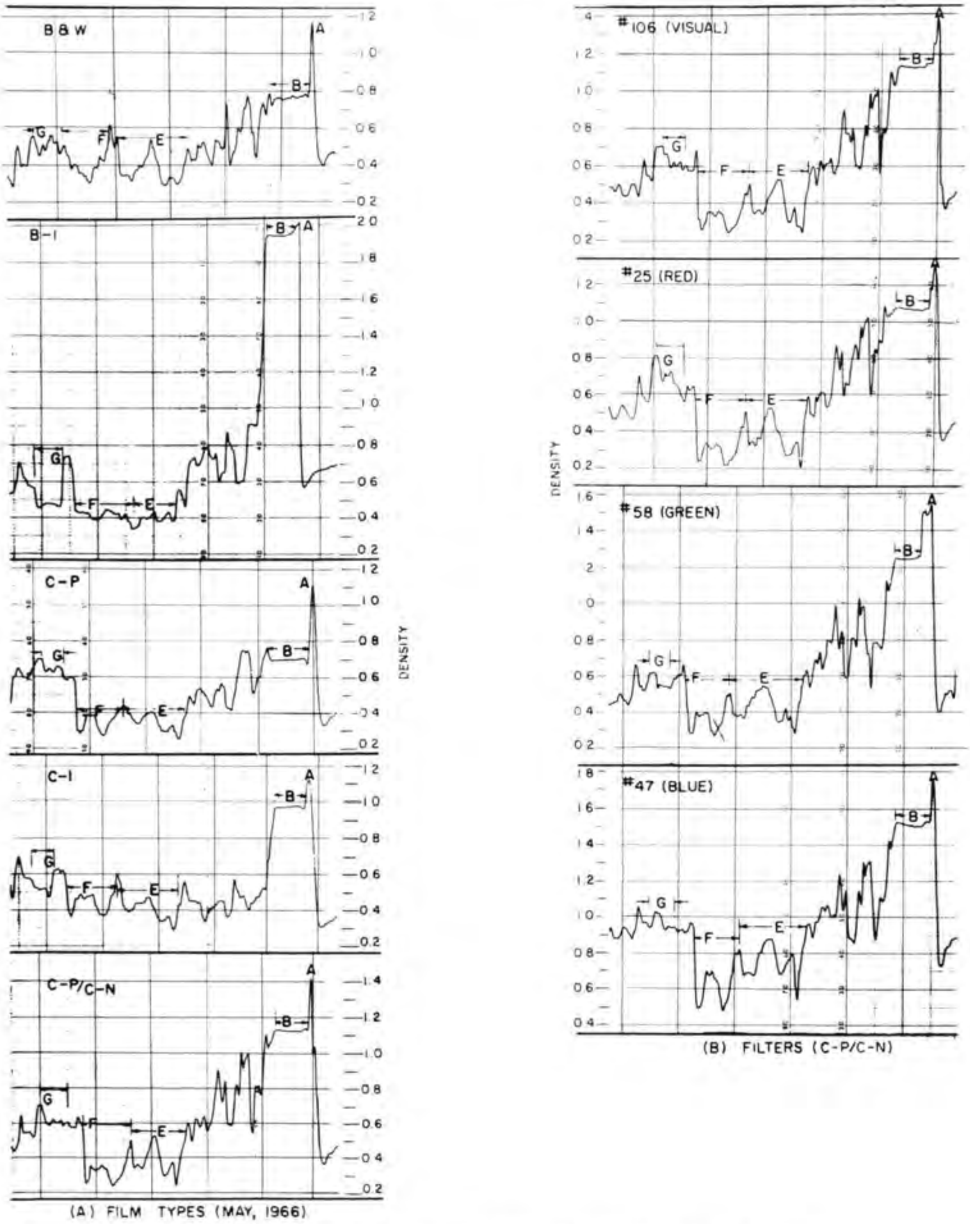


FIG. 1. Location of densitometer scan lines for study of parameter effects. Reference points: *A*, east bank (shadows); *B*, river; *C*, west bank; *D*, house; *E*, field (plowed); *F*, field (vegetated); *G*, tree covered knoll; *H*, fence line; *I*, small depression; *J*, forested slope.

sitometer and scans obtained on the transmission densitometer. Some of the variation in scans obtained were attributed to the aperture size, as the reflection densitometer is 4 mm., and the largest opening on the transmission densitometer is 3 mm. Actual variations due to the effects of the parameters evaluated, however, could be determined above this initial difference.

To simplify reference to the various film types and prints discussed, the following symbols are used in lieu of the film name:

Black-and-white photography	*B&W*
Black-and-white infrared photography	*B-I*



(A) FILM TYPES (MAY, 1966)

(B) FILTERS (C-P/C-N)

FIG. 2. Variations in densitometer scans due to film types and filters.

Color transparencies (positives)	*C-P*
Color negative film	*C-N*
Color infrared transparencies (positive)	*C-I*
Color print made from color negative	*C-P/C-N*

a. Variations Due to Film Types and Scanning Filters. The variations in the densitometer scans obtained on various film types, and for various densitometer filters on *C-P/C-N* film, are shown in Figure 2. The variations due to the various film types are shown in Figure 2A and were all scanned with the visual filter (No. 106W). In evaluating these scans, high densities indicate dark tones, while low densities indicate light tones.

On film types *B-I* and *C-I*, the river *B* and east bank shadows *A* have high densities as expected. On the other types, the shadow *A* has a greater density than the river *B*. Area *G*, a tree covered knoll, appears light on *B-I* and

C-I due to the high reflectance of vegetation in photographic infrared region. Area *G* appears in moderate tones on the other film types. Comparing fields *E* and *F* (both bare at this time of year), it is observed that very little variation is noted on the *B-I* whereas more contrast is noted in these two fields on the other types. This demonstrates an interesting point which was similarly noted on visual comparison of the various film types, that is, the contrast between various soils are least evident on *B-I* film than on other film types.

It is seen, by comparing only a few items that no two film types give the same density pattern. Thus, the scan developed in an attempt to obtain diagnostic patterns in any given area would vary depending on the type of film used.

Comparing the scans obtained with different filters on the same film type (Figure 2B) it is seen that the overall scan patterns are very similar, but some differences are noted. In fields *E* and *F*, the smallest contrast between the soil conditions present (depicted by less range in density) is obtained with the green filter. The others are about the same. The blue filter gives an overall darker tone as evidenced by the generally higher density. The greatest contrast between the bare fields *E* and *F* and the tree covered knoll *G* is obtained with the red filter. These features demonstrate that the use of different filters in the densitometer, on a given film type, would give different density patterns.

b. *Variations Due to Seasonal Effects.* The effect of seasonal variations on the densitometer scans is shown in Figure 3. It is evident from this figure that quite different densitometer scans are obtained for the same area at different times of the year. Since comparisons are made on *B-I*, tones due to water, shadows and vegetation are distinct. Actually the variations noted are due to several different factors. These are: (1) differences due to presence of crops in summer and fall relative to bare soil in spring (fields *E* and *F*); (2) differences due to sun angle as demonstrated by shadow effects (area *J*); and (3) differences due to time of day, also as demonstrated by shadow effects (areas *A* and *C*). In comparing fields *E* and *F* during the three dates, significantly different patterns are seen in the fields due to vegetation cover. Actually, on none of these dates are the fields completely covered with vegetation, but even the slight changes cause differences in tonal patterns and densitometer scans.

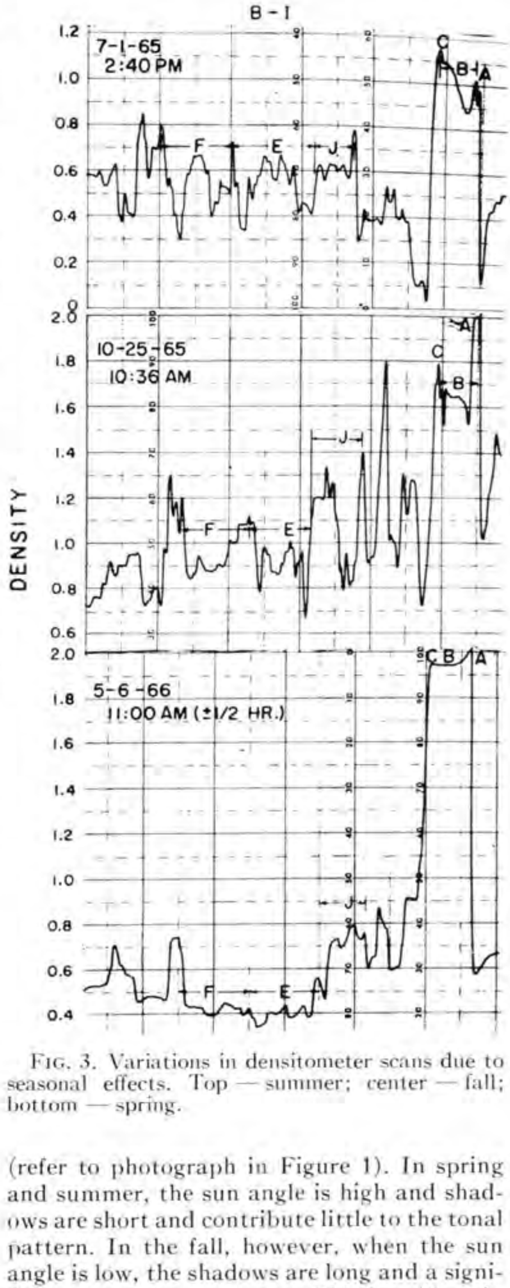


FIG. 3. Variations in densitometer scans due to seasonal effects. Top — summer; center — fall; bottom — spring.

The effect of the sun angle is best demonstrated by area *J* which is a tree covered area (refer to photograph in Figure 1). In spring and summer, the sun angle is high and shadows are short and contribute little to the tonal pattern. In the fall, however, when the sun angle is low, the shadows are long and a significant tonal change occurs. This is evident in the extreme tonal changes in area *J* in the fall scan.

The effect of time of day is indicated by points *A* and *C*. In the morning when the sun is in the east, the shadows on the east bank *A* are longer. As the shadow area is larger, point *A* has a greater density (fall and spring flight). In the afternoon when the sun is toward the west, the shadows on the west bank are longer and point *C* has a greater density.

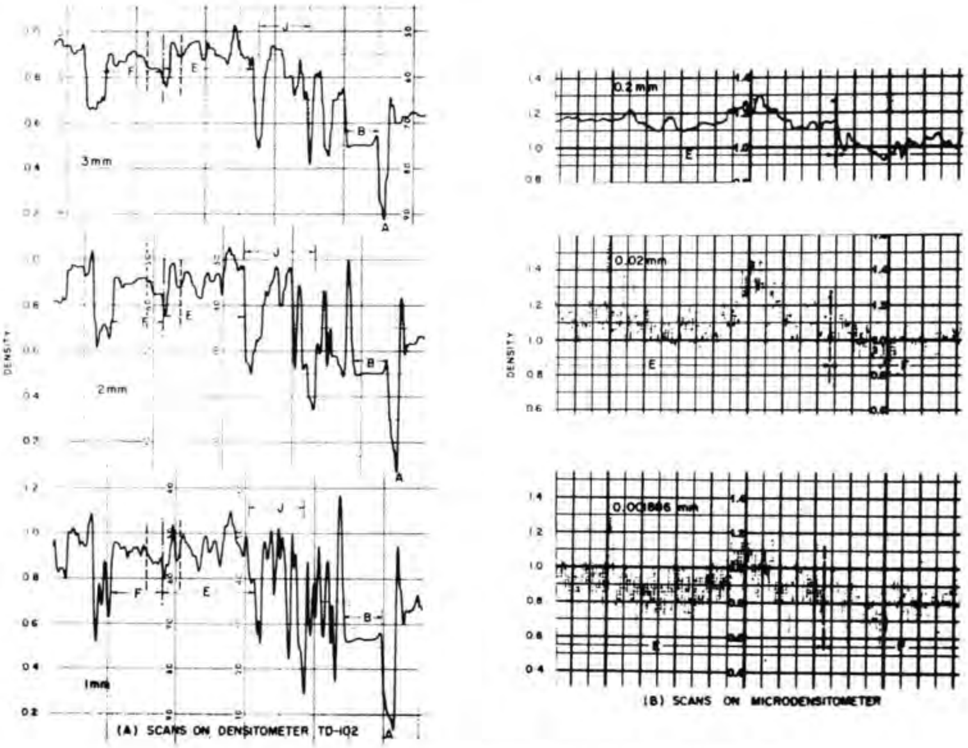


FIG. 4. Variations in densitometer scan due to aperture size.

c. *Variations Due to Aperture Size.* The effect of aperture size on densitometer scan patterns is demonstrated in Figure 4. These scans were measured on a *B-I* negative. The scans with circular aperture sizes of 3 mm., 2mm., and 1 mm. (Figure 4A) were obtained on the transmission densitometer at an approximate scanning rate of 0.1 inch/second, or one inch on the scan is equivalent to one inch on the photograph. The scans with circular effective aperture (actual aperture/system magnification) sizes of 0.2 mm., 0.02 mm. and 0.001886 mm. (Figure 4B) were obtained on a microdensitometer at a scanning rate of 4 mm/minute, or 1 inch on the scan is equivalent to approximately 0.08 inch on the photograph. The microdensitometer scans were performed by the U. S. Army, Terrestrial Science Center in New Hampshire. Because of this slow recording speed and correspondingly large horizontal scale, only a portion of fields *E* and *F* scan lines are included in Figure 4B.The portion included is indicated by the dashed vertical lines on the scans in Figure 4A. As noted by the sequence of fields *E* and *F*, the scans on the microdensitometer (*E* to *F*) are 180 degrees opposite to those (*F* to *E*) on the transmission densitometer. The break between the fields is shown by a dash-dot line.

In analyzing these scans on the *B-I* negative, it must be realized that the density-tonal relationships are reverse to the previous examples shown for positive prints. On the negative, the light tonal patterns present on the photographs are recorded in higher densities and the darker patterns in lower densities.

Comparisons of the scans in Figure 4 demonstrate that the number of significant changes in density obtained on a densitometer scan is inversely proportional to the aperture size. With large size apertures, more area is exposed to the scanning spot at one time; consequently, an average of the light and dark tones covered by the scanning spot are recorded. As the aperture size is decreased, finer and finer tonal patterns are measured and more detail recorded. If the aperture size is reduced still further, a point is reached where the scans are recording the granularity of the film and the information desired is lost in the detail. These features are observed when comparing the patterns for field *E* and *F* on the six scans and the patterns for area *J*, the tree covered slope, on the three densitometer scans. Taking *J* first, it is noted that as the aperture size decreases, the amount of detail and degree of contrast observed increases. In the 3 mm. scan, the value is an average of the tones due to the individual trees and their shadows, while in the 1 mm. scan, these items are individually scanned. In comparing the six scans for fields *E* and *F*, it is apparent that the amount of detail and degree of contrast obtained increases as the aperture size decreases. For example, the range of density shown in the designated band on the 3 mm. scan is about 0.2 density units, while on the 0.001886 mm. scan it is about 0.8 density units. The scan patterns for the smallest two aperture sizes indicate that possibly the effects of film granularity are being measured.

d. *Variations Due to Scale of Photography.* The analysis of the effect of scale of photography is somewhat similar to that of aperture size. However, instead of varying the size of the aperture in studying a photograph at a given scale, the aperture was maintained constant and different scale photographs were scanned. To obtain the same final scale of the scan pattern, the speed of the recorder and the rate of scanning were adjusted for each photograph or strip of photographs.

The scans indicated in Figure 5 were performed on B&W photographic prints at the scales shown. The area scanned in this example was different than that scanned in the previous examples. By comparing the amount of detail present in areas *K* (plowed field) and *L* (gravel pit), it is evident that as the scale becomes larger, the amount of detail obtained increases.

e. *Summary.* The previous examples have shown the effects of just a few parameters on densitometric scans to evaluate patterns on aerial photographs. Numerous other parameters such as film exposure, processing, and printing affect the scan patterns. All of these parameters are influencing the density values obtained over and above that due to the tonal factors representing the terrain features of interest, e.g., tonal factors due to vegetation, culture, moisture conditions, intrinsic soil color and composition of materials.

Analysis of these various density scans led in this study to the conclusion that one would not be able to develop diagnostic patterns for various terrain features from measurements on a single film type taken at a given point in time. In comparing the various scans, it was noted that there was more variability within a given terrain feature due to the various parameters, than between terrain features of interest.

ISOTONAL AND ISOCHROMAL MAPPING

Limited attempts were made to prepare isotonal maps and isochromal maps in an effort to delineate areas of similar terrain conditions. The maps were largely prepared by contouring from point density readings taken on a one-half inch grid system. Some attempts were also made to prepare the maps from the continuous scan data.

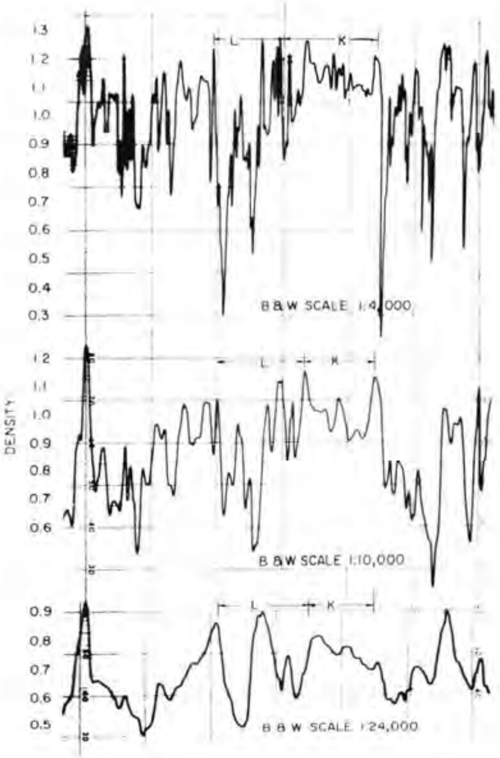


FIG. 5. Variations in densitometer scan due to scale of photography.

In order to determine the color tones present for isochromal mapping, a special technique was developed in which a standard color description (Munsell color designation) was determined from the four filter density readings (visual, red, green, blue). Upward of 1500 different colors can be differentiated. This technique is adequately described in the literature.[2,3]

The maps produced by isotonal and isochromal methods were compared with the original photographs by overlying the maps on the photographs. Both forms of maps prepared from the grid readings were unsuitable because insufficient grid points were obtained to delineate significant tonal boundaries adequately. Comparisons of the limited areas mapped from the continuous scans indicated that there were zones on the isochromal map that contained color zones comparable to those on the original photograph, some of the zones delineating significant terrain boundaries. This same condition was not noted on the isotonal map because of the variety of terrain features which had the same density. The problems of reduction of data and inaccuracies of point location on the continuous scans limited the full evaluation of the continuous scan method.

The development of isochromal mapping does offer a method for automatically mapping various tonal patterns present on color photography, many of the patterns representing significant boundaries. This technique was not fully developed in this project, but softwear and hardware are available to accomplish this task. Further work is presently underway on this problem in the Office of Research and Development of the Bureau of Public Roads. In the development of this technique it should be remembered that the study is concerned with one type of film taken at one period of time. The influence of the various parameters discussed in the previous sections are equally applicable to this technique.

NORMALIZED SPECTRAL RESPONSE SIGNATURES

The third method attempted, in efforts to develop diagnostic patterns for various terrain elements, was based on the use of the University of Michigan multichannel sensor. The multichannel sensor simultaneously obtained up to 18 channels of imagery ranging from the near ultraviolet to the far infrared regions. All the channels were at the same scale, resolution and format.

To examine some of the tonal relationships existing for various terrain features, the reflectance of various items were measured in each band with the reflection densitometer. The density values obtained by the densitometer were converted to reflectance by the relationship

$$\text{Reflectance} = \frac{1}{\text{antilog}_{10}\,\text{Density}}. \qquad (1)$$

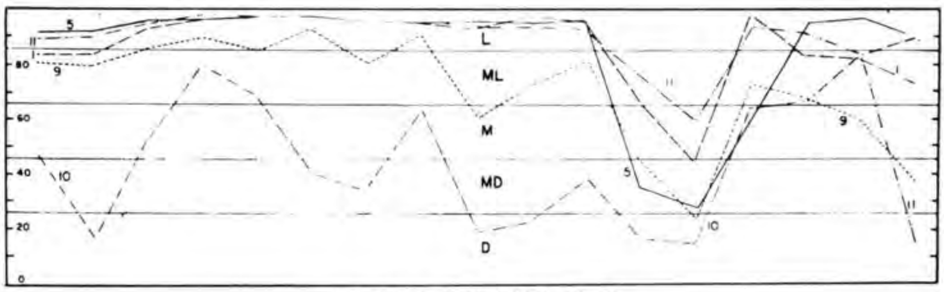
These values were then normalized for each band by determining the reflectance of the lightest object R_L and the darkest objects R_D in each band and using these as the one hundred percent and zero percent reflectance points respectively. The normalized reflectance Rn for each object was then determined by the following method:

$$R_n = \frac{(\text{Reflectance of Object} - R_D)}{R_L - R_D} \times 100 \text{ percent.} \qquad (2$$

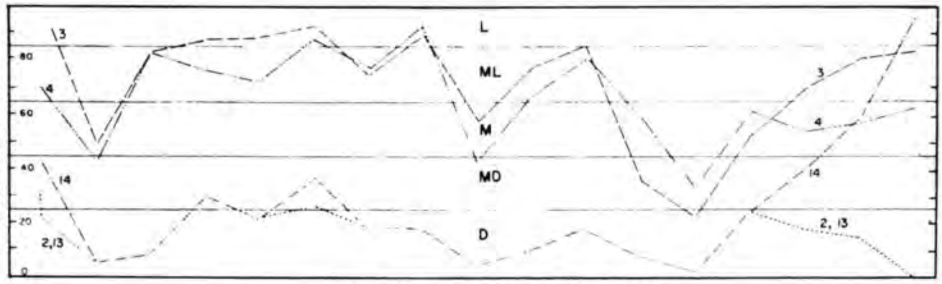
As both reflectance and emittance were being evaluated, the values plotted were referred to as normalized response. These

FIG. 6. Location of points measured on multichannel imagery. Black-and-white mosaic (May 6, 1966).

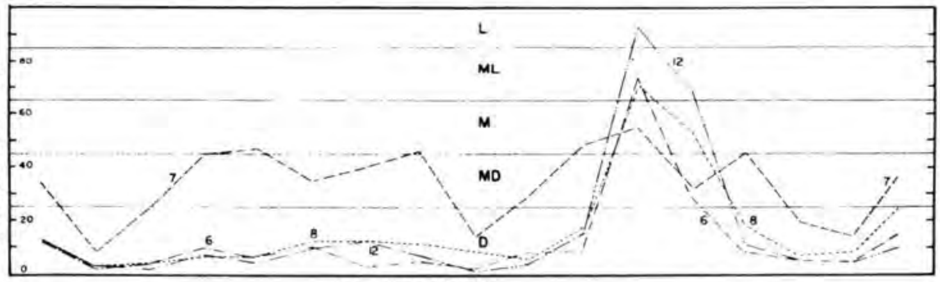
Point No.	*Soil or Rock Unit*	*Condition*
1	Thick loess/glacial till	High position—bare
2	Glacial till	High position—plowing in progress
3	Glacial till	High position—recently plowed
4	Glacial till	High position—plowed a few days ago
5	Sandstone	Small exposure
6	Glacial till	Covered with winter wheat
7	Glacial till/Sandstone	Pasture, sandstone exposed in places
8	Glacial till/Sandstone	Pasture
9	Glacial till	High position
10	Glacial till	Depression
11	Glacial till	High position
12	Glacial till	Covered with winter wheat
13	Flood plain	Plowing in progress
14	Flood plain	Recently plowed
15	Sand dunes	Bare in places



(a) SOILS AND ROCK UNITS



(b) EFFECTS OF FARMING PRACTICES



(c) VEGETATION

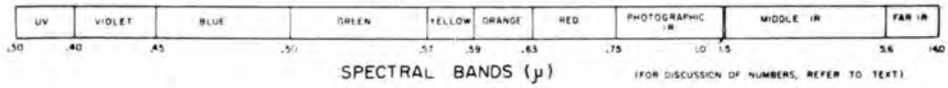


FIG. 7. Spectral response signatures for various terrain features.

normalized values were plotted in the respective region of the spectrum and the points connected to obtain a spectral response curve or signature for the various terrain features of interest.

An aerial photographic mosaic showing the conditions existing at the time the multichannel imagery was obtained and the location and description of the various terrain features measured with the reflection densitometer are shown in Figure 6. Examples of the spectral response signatures obtained for the various target materials are included in Figure 7. These curves are divided into three groups. Figure 7a includes spectral response signatures for bare soils and rock units; Figure 7b includes spectral response signatures for bare soils whose tones vary from those in Figure 7a due to farming practices; and Figure 7c includes spectral response signatures for various vegetation conditions present in the area. The abscissa representing spectral bands is not plotted to scale. The wave lengths shown at the bottom are only intended to indicate the regions of the spectrum included in each of the spectral bands delineated.

The five bands delineated in Figure 7, *L* light, *ML* medium light, *M* medium, *MD* medium dark and *D* dark are qualitative ratings. They were used to compare the relative tones on the multichannel imagery to those on other forms of photography and imagery where comparative measurements were not possible.

The spectral response curves in Figure 7a demonstrate the similarities and differences present for sandstone (curve 5), glacial till soils of various topographic positions (curve 9, eroded slope; curve 10, depressional area; curve 11, high topographic position), and a glacial till soil overlain by 4 to 5 feet of loess (curve 1). All of these units can be separated because of distinct differences in various portions of the spectral region. For example curves 1, 5 and 11 are similar throughout the visible region, but curve 5 shows a darker tone than 1 and 11 in the photographic infrared region, whereas curve 11 shows a darker tone than curves 1 and 5 in the far infrared region. Curves 9 and 10 similarly have distinct differences to aid in separating them from each other and from the other units.

The effect of farm practices on the tones obtained in the various bands is demonstrated in Figure 7b. All of these curves represent soils recently plowed. Curve 4 represents a field plowed a few days before the flight. Curves 3 and 14 represent fields plowed the morning of the flight (flight performed in the afternoon) and curves 2 and 13 represent areas being plowed during the flight or a very short time prior. Soils represented by curves 2, 3 and 4 are glacial till soils predominantly in the high topographic position and those of curves 13 and 14, sandy soils of the flood plains.

The effects of the plowing are to expose at the surface the wetter and darker colored subsoils. When the soil is first turned over, the moisture effect is the controlling factor, resulting in darker tones in all bands regardless of texture (e.g., curves 2 and 13). As these soils dry out, the effect of moisture is decreased and that of soil color becomes prominent (e.g., curves 3, 4 and 14). Note curves 3 and 4 (drying ½ day and 2 days, respectively) are fairly similar and both resemble curve 9 (Figure 7a), the eroded glacial till soil, in which similarly, the subsoils are exposed. These examples demonstrate that in the matter of only a few hours, drying of soils can vastly change tonal patterns on imagery.

The last group of curves in Figure 7c show the differences in spectral response signatures obtained due to various vegetation conditions. Curves 6 and 12 represent fields of winter wheat while curves 7 and 8 represent pasture fields. It is noted that pasture fields can generally be distinguished from winter wheat by lower reflectance in the photographic IR region. It is further noted that all the curves in this figure indicate that the presence of vegetation results in dark or medium dark tones in all bands but the photographic IR. As the previous curves for soils indicate that soils have low response in the photographic IR, this is an excellent band for distinguishing tonal effects due to vegetation from those due to soils.

The difference in response between the pasture fields, curves 7 and 8, is that the field containing point 7 has bedrock close to the surface and its influence is indicated by the light streaks in the field (see Figure 6). This affects the overall tonal response resulting in slightly lighter tones. The differences between the fields of winter wheat, curves 6 and 12, are a little more difficult to explain. These curves are fairly similar in all bands but the photographic IR. In that band curve 6 is darker. From investigation of this phenomena in the field, it was determined that field 6 was planted two weeks earlier than field 12. In addition, it was discovered that this field had been planted in corn the year before whereas field 12 had been planted with a low cover crop. It has been suggested by a botanist that the tonal patterns may be reflecting vegetation differences due to varying nitrogen levels in the soils. This could not be verified, but similar effects of previous planting history on variations in tonal patterns obtained for similar crops has been reported by C. E. Olson.[4]

One final feature can be noted in reviewing the spectral response curves in Figure 7. Many of the curves for soils (but not all) show a dip in the yellow-orange bands. Thus tonal differences between some soils are increased in this band. This confirms the feature previously noted in Figure 2A, that the greatest contrast between soils are obtained when analyzing color photography using a red filter (Wratten 25). This filter limits the range to approximately 0.60 to 0.70 microns which covers this region of greater contrast.

The examples discussed in Figures 6 and 7 clearly demonstrate the influence of cultural factors (e.g., farming practices) on the final density patterns obtained and the added difficulty in attempting to arrive at diagnostic tonal patterns. Just the matter of plowing the field or the sequence in planting crops affected the tonal patterns obtained. It further points out the need for field control during flights to determine the existing ground conditions. However, these examples show that multichannel imagery does provide a method whereby these various factors can be distinguished. The spectral response signatures obtained by density measurements combined with normalizing procedures demonstrate a valuable method for evaluating the response of various terrain features in different regions of the spectrum from an airborne platform. This should prove to be an excellent method for determining spectral bands of maximum contrast for the separation of features of interest. The main problem with the use of this system is that the amount of imagery obtained for analysis by normal interpretative methods becomes voluminous. For example, using just five basic tonal patterns and 15 channels, there are 5^{15}, or over thirty billion, possible tonal combinations. This demonstrates the need to develop techniques to analyze this system automatically. This approach is being investigated at The Bureau of Public Roads and by other research groups.[5,6]

The spectral response curves shown in Figure 7 still represent the conditions existing at one period of time. Thus, the influence of some of the parameters previously discussed, such as seasonal effects, aperture size and scale, are equally applicable to this method.

CONCLUSIONS

This paper has discussed some investigations into methods to interpret automatically, various terrain features based on the analysis of the "tonal" pattern element. Three approaches were investigated. These included: (1) analysis of continuous densitometric scans; (2) preparation of isotonal and isochromal maps; and (3) development of normalized spectral response signatures from multi-channel imagery. To evaluate these methods, a variety of film types and imagery types, obtained from nine flight missions spread over a 13-month period were analyzed.

Results of this study indicate the following:

- The preparation of isochromal or isotonal maps from point readings on a grid basis is not feasible. It is necessary to use continuous densitometric scans in order to be able to distinguish the significant boundaries.
- Differentiation of significant terrain features are not possible by isotonal mapping or from measurements of continuous scans on a single film type. In the former case, significant features could not be differentiated because several terrain features had the same film density on the photography. In the latter case, the influence on density patterns of such parameters as film type, season of year, scale of photography, scanning filter, aperture size of densitometer and cultural features cause more variations *within* a given terrain feature than occur *between* terrain features of interest.
- The use of multichannel imagery offers the greatest potential for automatically delineating various terrain features. The imagery is obtained at the same scale, resolution and format, and normalized spectral response curves for various terrain features can be prepared. This permits visual or automatic determination of the bands of the spectrum providing the maximum contrast or unique patterns for the identification of terrain features.
- The technique developed in this research project for automatically differentiating various colors on color photography by means of densitometric measurements offers a potential method for automatically preparing isochromal maps. This has the immediate application for the identification or separation, at a given period of time, of those terrain features which are directly related to intrinsic color.

RECOMMENDATIONS

The conclusions obtained for this study were obtained from analysis of a limited number of terrain features under one environmental condition. All the study attempted to accomplish was to give some indication of the variety of parameters affecting the tonal patterns obtained and to indicate what approach or approaches offered the best potential for ultimately achieving the goal of automatic interpretation. Further work is needed in analyzing terrain features in a variety of environments under comparable conditions of time (e.g., all spring coverage). Extensive work is needed in further developing the techniques for reducing the data on the photography and imagery into a format that can be handled by computers. It is expected that in the ultimate solution, all the pattern elements will have to be utilized, and not that of tone alone.

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