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CR-146365

LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES

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November 3, 1975

Prepared for:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. Report #3	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle LAND CLASSIFICATION OF SOUTH-CENTRAL IOWA FROM COMPUTER ENHANCED IMAGES		5. Report Date November 3, 1975	
		6. Performing Organization Code	
7. Author(s) James R. Lucas, IGS; James V. Taranik, EROS; Frederic C. Billingsley, JPL		8. Performing Organization Report No.	
9. Performing Organization Name and Address Iowa Remote Sensing Laboratory Iowa Geological Survey 123 North Capitol Street Iowa City, Iowa 52242		10. Work Unit No.	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Goddard Space Flight Center Greenbelt Road Greenbelt, Maryland 20771		13. Type of Report and Period Covered Type II Report 8/3/75 to 10/3/75	
		14. Sponsoring Agency Code	
15. Supplementary Notes Technical Monitor: James Broderick			
16. Abstract see page ii Original photography may be purchased from: EROS Data Center 10th and Dakota Avenue Sioux Falls, SD 57198 ORIGINAL CONTAINS COLOR ILLUSTRATIONS			
17. Key Words (Selected by Author(s)) Land Classification, South Central Iowa, Computer Enhanced Images		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages 53	22. Price*

ABSTRACT

The Jet Propulsion Laboratory (JPL) computer enhanced imagery has far greater capabilities for land-use planning purposes than the EROS Data Center's standard products. Two enhanced false-color negatives from multispectral scanner scenes, dated 15 April 1974 and 29 August 1972, were printed at a scale of 1:125,000 to form the basis for land-use interpretations in the Wapello County, Iowa test site. The use of geomorphic principles proved valuable in the interpretation of the April LANDSAT-1 scene to form valuable generalizations for planning purposes on soil associations, topography, alluvial valleys, and agricultural land-use. The August scene superior in providing information on urban extent, transportation networks, forest cover, and water bodies. The attainment of additional land-use categorization in Wapello County may be possible through altering specific image processing techniques. A discussion of the characteristics of contrast stretching, the Optronics film recorder, the construction of false color composites, and the printing of color negatives is included as it may potentially relate to the improvement of image interpretation. In addition, the implementation of the Unicolor photographic printing system has given the Iowa Remote Sensing Lab the ability to produce inexpensive, high-quality color prints which are judged to be a very significant step in optimizing the use of computer enhanced imagery for land-use planning purposes.

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Introduction

The principal objective of NASA contract NAS5-20832 is to produce land-use classification maps for south-central Iowa from computer-enhanced LANDSAT images. During this third quarter, the Iowa Geological Survey Remote Sensing Laboratory (IGSRSL) received from the Jet Propulsion Laboratory (JPL) two very high quality color negatives for an image interpretation test site, Wapello County, which is in the eleven-county contract area. The color prints generated from these negatives are the data source for the land-use maps created for Wapello County. Work sessions on the EROS Data Center's IMAGE 100 system, in addition to the interpretation with JPL personnel, form the bases for the discussion of image processing in this report. A detailed summary of image interpretation from multi-spectral scanner (MSS) enhanced imagery for Wapello County is discussed as it relates to landscape systems and land-use activities. Future research endeavors are also outlined for the next quarter. The contract's financial status is summarized in Table I.

Computer-Enhanced Imagery from the Jet Propulsion Laboratory

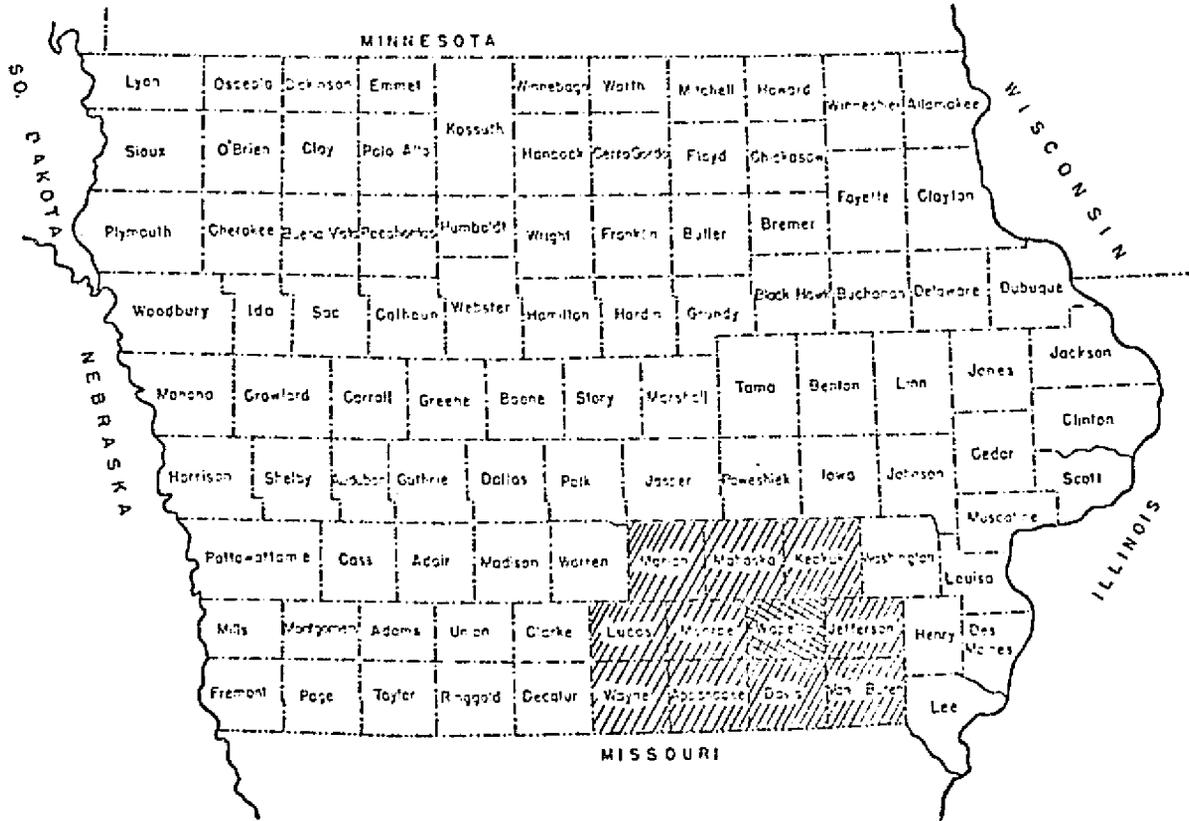
During this quarter, the Iowa Remote Sensing Laboratory received from JPL two high quality, false-color negatives. Recorded on these negatives are individual subscenes of Wapello County, Iowa, taken by the LANDSAT multispectral scanner on 29 August 1972 and 15 April 1974. Wapello County was chosen as a test area for image interpretation purposes because it is centrally located in the contract study area and is considered to be typical of southeastern Iowa (see Figure 1). Figures I and II in Appendix A are color prints of the county area made from these negatives. The MSS scene identification numbers are included on the figures. A linear contrast stretch was applied to both subscenes during image processing. The Optronics Photowrite System recorded on film the scene's picture elements with a 100-micron spacing. The color prints produced from these negatives form the bases for much of this report's discussion on image interpretation.

Trips to the EROS Data Center

Three trips to the EROS Data Center (EDC) have been made during this quarter. The analysis sessions which were scheduled on the IMAGE 100 system have been an important contributor in understanding computer enhancement techniques. Some of the results of these analysis sessions are discussed later in this report. We also feel that it is appropriate to mention that the hospitality extended to the IGSRL personnel by Chief Don Lauer and his staff in the Applications Assistance Branch

Figure 1

Location Map of the Eleven-County Study Area



 Eleven-County Area

 Wapello County

has been outstanding! Our sincere thanks are given.

In addition to utilizing the IMAGE 100 system, computerized LANDSAT image searches have been conducted at EDC. The eleven-county study area is somewhat problematic in satisfying the contract's image requirements, since the area spans two LANDSAT tracks. One satellite scene, therefore, will not cover the entire study area. In order to ensure that all potentially useful images in the computer's memory would be found, three point searches were initiated over the southern Iowa area. The 45-mile search radii for these three points completely covered the contract area. All dates were requested for LANDSAT 1 and 2 imagery with a 30 percent maximum cloud cover and minimum rating of 5 on band quality. As a result of these searches, the following three computer-compatible tapes (CCT's) were identified and ordered:

Date of Tape	Identification Number	Band Quality (Band)				Percent Cloud Cover
		#4	#5	#6	#7	
17 May 1975	5028 16070 5 NO	8	8	8	8	0
2 July 1975	2161 16214 5 NO	8	8	8	8	10
19 Aug. 1974	1757 16124 5 NO	8	8	8	8	0

Appropriate accompanying imagery was also acquired. This order depletes the imagery account (#20660), leaving \$200.00 in the CCT account (#B0660).

Discussion of Image Processing

I. JPL's VICAR System Format

The standard LANDSAT image has its picture elements (pixels)

arranged in a matrix which is 2340 lines by 3240 columns. In the line direction, each pixel is sampled to integrate spectral reflectance over 79.1 meters on the earth's surface while the column direction is sampled so that the integration of reflectance data is over 57.2 meters. The resulting pixel on a standard LANDSAT scene is rectangular, integrating reflectance data over an area that is 57.2 meters by 79.1 meters. Figure 2 illustrates the pixel arrangement for a standard LANDSAT scene.

When a computer-compatible tape is translated into the Jet Propulsion Laboratory's VICAR (Video Image Communication and Retrieval) format, the picture elements are resampled so that they are square. This resampling to square pixels (called aspect ratioing) is accomplished by linear interpolation between the "over-sampled" digital numbers (DN's) in the column direction of the standard LANDSAT scene to generate a new digital number which corresponds to the spectral reflectance integrated over 79 meters. The resulting matrix of digital numbers assigned to each picture element is 2340 lines by about 2340 columns. Each pixel in the VICAR format integrates spectral reflectance over 79.92 meters square (see Figure 3). This slightly larger picture-element resolution of 79.92 meters square, compared to the standard product's 79.1 meters in the line direction, is a statistical result due to geometric corrections made for: (1) skew, (2) panoramic distortion, (3) mirror scan velocity profile, and (4) addition of synthetic pixels.

The correction for image skew is necessary to compensate for

the earth's movement relative to the satellite's as the scene is being taken by the multispectral scanner. Another geometric adjustment for LANDSAT scenes corrects the panoramic image distortion resulting from the scene being tangent to the earth's spherical surface at only one point. Since the MSS mirror-scan velocity is not constant because of the speeding up and slowing down of the scanner mirror, geometric corrections are also necessary for this phenomenon.

Because the length of scan lines that comprise a scene vary slightly due to variations in the period of the mirror, synthetic picture elements are generated on the computer at the NASA Goddard Data Processing Facility to adjust all scan lines to the same length. The scan lines are lengthened by inserting these synthetic pixels at regular intervals, as needed, to obtain the desired line length. The synthetic pixel is a duplicate of the pixel DN value preceding it on the scan line. However, since VICAR format requires a resampling to square pixels, which in turn adjusts the line lengths, these synthetic pixels are not needed and are consequently removed.

If lines of missing data occur in a LANDSAT band, synthetic lines may also be created by linear interpolation between the digital numbers in the lines surrounding the missing line data. This VICAR program is called ERTSFIX. The advantage of ERTSFIXing a scene is that an image is created which is free from the distraction of missing scan lines. For visual interpretation purposes this cosmetic operation is very effective, while for machine

Figure 2

EROS Data Center LANDSAT Standard Product--Full Frame Scene

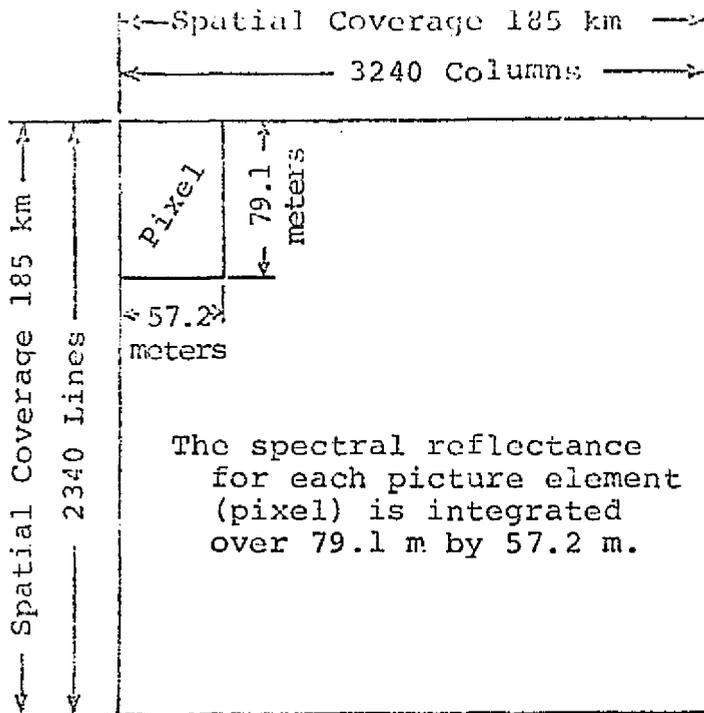
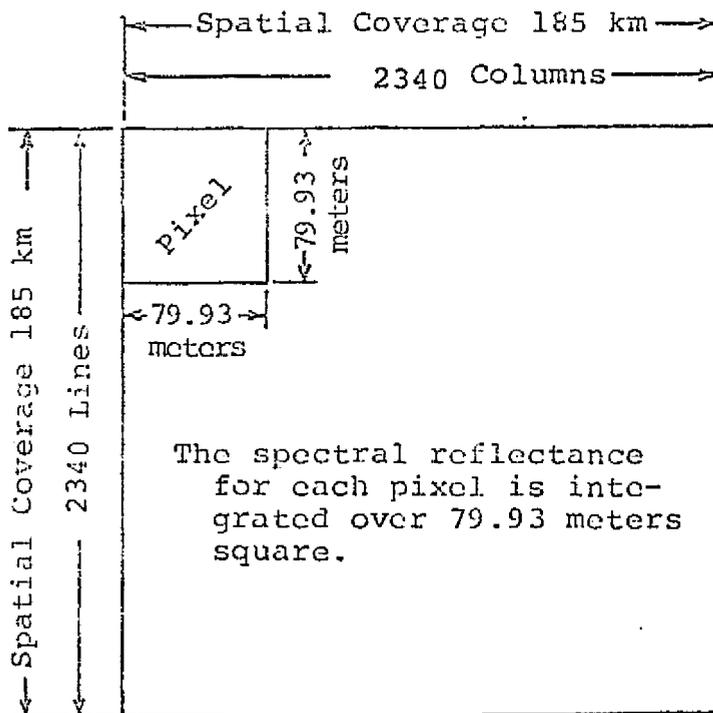


Figure 3

Jet Propulsion Laboratory Computer Enhanced VICAR Product--Full Frame Scene



185 km = 115 st mi

classification purposes, the extreme values for missing data are eliminated by the interpolation between DN values. The use of synthetic DN values for machine classification, therefore, must be carried out with caution.

II. CCT Reflectance Data Transformation and Display

On a standard CCT, bands 4, 5, and 6 have a seven-bit precision. Seven computer bits determine the value for the pixel's digital number. The dynamic range possible for seven-bit precision is 0 to 127 ($2^7 = 128$). Dynamic range in this context is defined as the possible values that a set of digital data can take, which is dependent upon the level of precision used. This, in turn, means that the data base for pixels in bands 4, 5, and 6 have 127 possible levels of gray. Band 7, however, has a six-bit precision giving it a dynamic range of 0 to 63 ($2^6 = 64$). Pixels in band 7 have 63 possible levels of gray.

Image-processing techniques used at the Jet Propulsion Laboratory scale up both the six- and seven-bit data to an eight bit precision. The dynamic range for eight bit precision is 0 to 255 ($2^8 = 256$). With this increase in the dynamic range, the LANDSAT picture elements have a greater number of possible gray values which may be assigned to them. The greater the number of gray levels an image has, the more levels of contrast it will possess. Contrast is defined here as the amount of visible difference between the darkest and lightest tones in a film or print. This scaling up of CCT data does not transform the relation-

ships between the scene's spectral reflectance values assigned to the picture elements. It does, however, create a greater range of values between digital numbers because more gradations exist within the expanded dynamic range.

When scaling up of CCT data is executed on the VICAR system, a bit shift occurs which gives bands 4, 5, and 6 an actual dynamic range of 0 to 254. Band 7 has an actual dynamic range of 0 to 252. For all practical purposes, these bit losses in the dynamic range are insignificant.

To determine a LANDSAT scene's spectral reflectance characteristics, histograms are constructed for each of the four spectral bands, showing the digital numbers versus their frequency of occurrence. The digital numbers refer to image densities or levels of gray which are assigned to the picture elements. The distribution of digital numbers in a spectral histogram relates directly to a scene's tonal characteristics. For example, Figures I and II in Appendix A are LANDSAT-1 false color composites for Wapello County, Iowa. Figure I is a multispectral scanner scene taken on 15 April 1974, while Figure II is an MSS image obtained on 29 August 1972. The tonal characteristics of the April scene are generally darker than those of the August scene. Analysis of the spectral histograms illustrates this point. Figure 4 is the spectral histogram for band 6 of the April scene; Figure 5 is the spectral histogram of band 6 of the August image. When a comparison is made between these two spectral histograms, band 6 for the April image possesses more digital numbers (or picture

Figure 4

Histograms for Wapello County, Iowa

15 April 1974, LANDSAT 1

Scene ID: 1631-16161

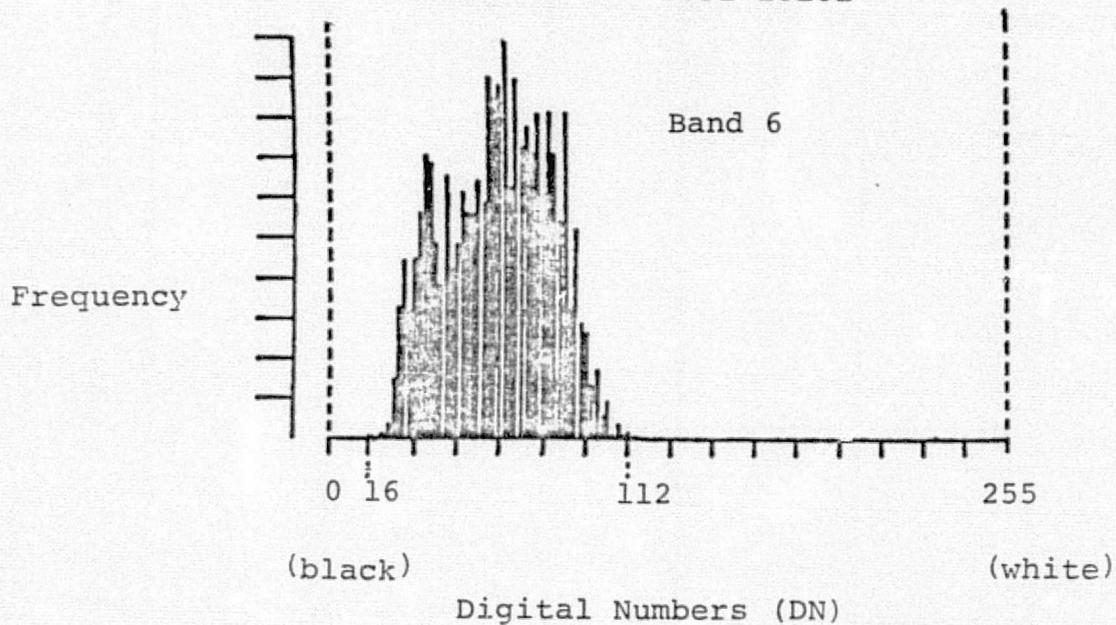
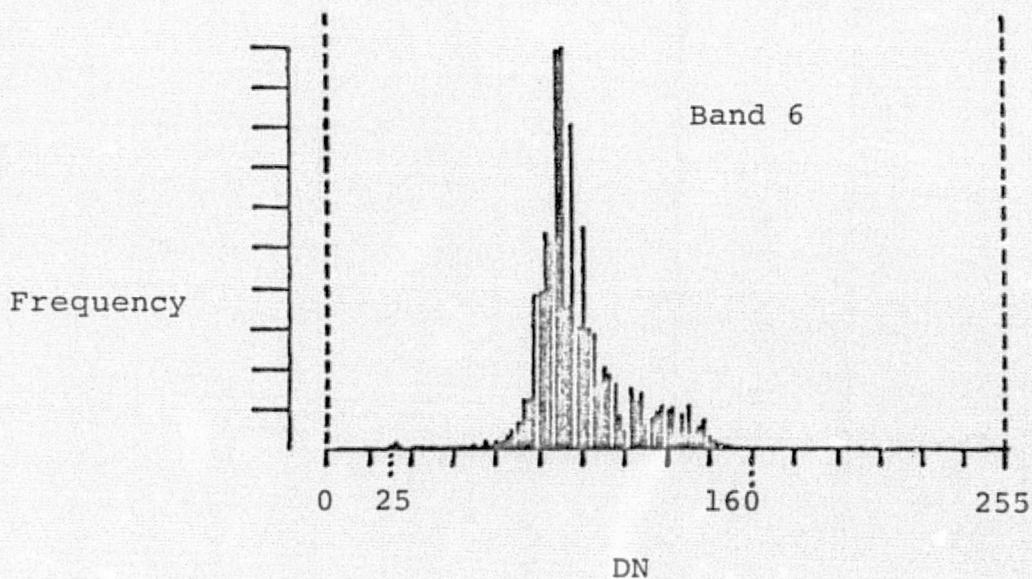


Figure 5

Histograms for Wapello County, Iowa

29 August 1972, LANDSAT 1

(Scene ID: 1037-16213)



elements) corresponding to dark tonal values than the August scene. The distribution of digital numbers in band 6 for the April scene falls almost entirely between DN values of 24 and 104, while the DN range for the August scene's band 6 falls mostly between 64 and 144. Since a DN value of 0 corresponds to black (zero reflectance) and a DN value of 255 corresponds to white, the band 6 spectral histograms indicate that the 15 April 1974 scene will have darker tonal characteristics than the 29 August 1972 scene.

III. Contrast Stretching

To expand the distribution of digital numbers (or image densities) across the total eight-bit dynamic range (256 steps), a method called "contrast stretching" is employed. Figures 4 and 5 illustrate how LANDSAT spectral reflectance data are sometimes grouped into a small portion of the total possible dynamic range. To expand this distribution of reflectance data, mathematical algorithms are implemented to transform the digital numbers into a new distribution which extends the DN values across the entire dynamic range. Since these new distributions are generated on a computer mathematically, the form is dependent upon the transfer function used--linear, Gaussian, ramp cumulative distribution, etc.--depending upon the desired result. Figures 6 and 7 are examples of linear, contrast-stretched spectral histograms of band 6 for the Wapello County scenes found in Appendix A. When these histograms are compared to those in Figures 4 and 5, the general forms of the distri-

Figure 6

Histograms After Linear Contrast Stretch for Wapello County, Iowa

15 April 1974, LANDSAT 1

(Scene ID: 1631-16161)

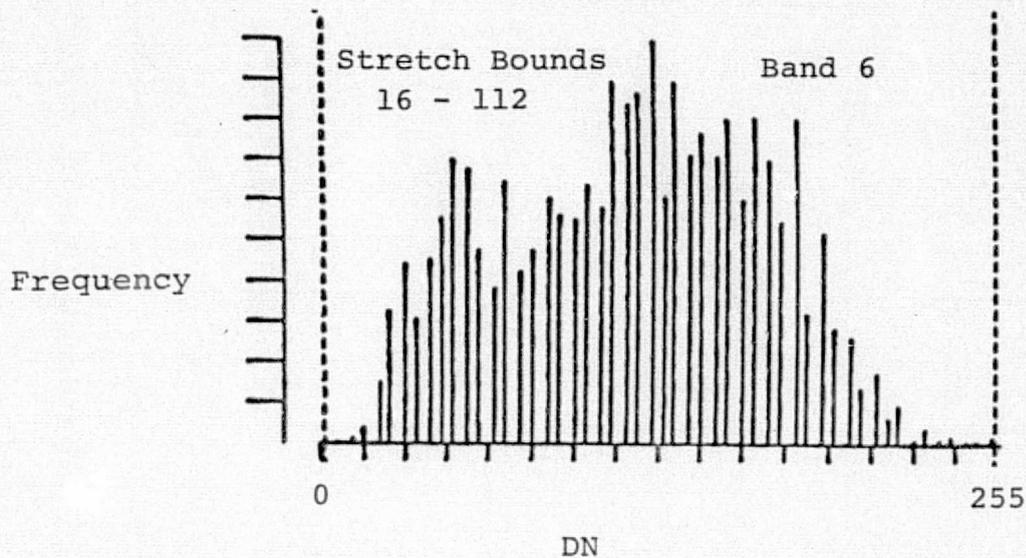
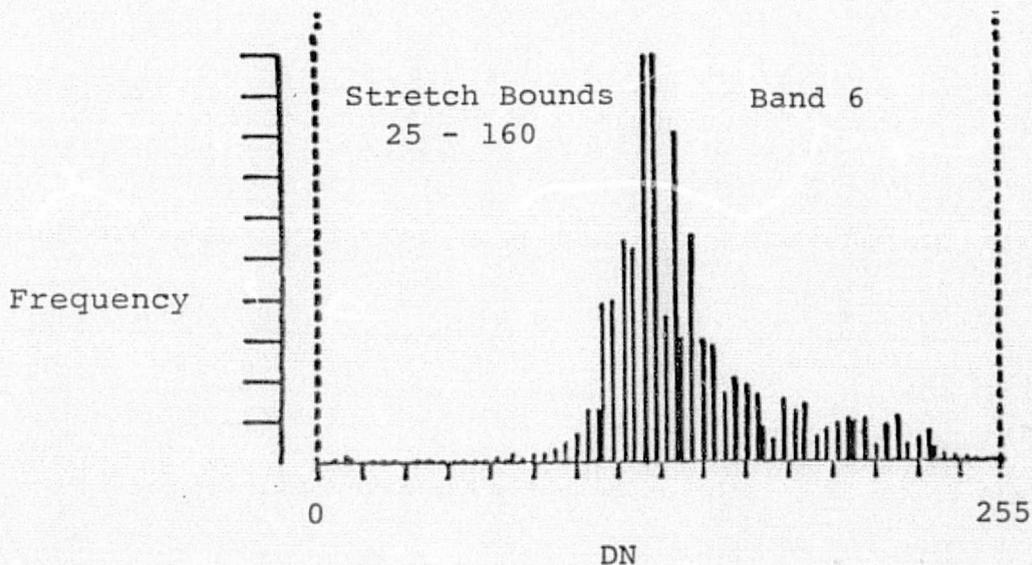


Figure 7

Histograms After Linear Contrast Stretch for Wapello County, Iowa

29 August 1972, LANDSAT 1

(Scene ID: 1037-16213)



butions are similar, the only difference being the extent of the dynamic range covered. More levels of gray are employed in the contrast-stretched bands which, in turn, give a greater scene contrast.

To further increase the limits over which the spectral data may be expanded, the end portions of the spectral histograms, usually $1\frac{1}{2}$ to 3 percent of the total DN values, are transformed to digital numbers of 0 (corresponding to black) or 255 (corresponding to white). This transformation of picture elements to white and black is known as saturating the end portions of the spectral histogram. The term "stretch bounds" of a band refers to the end-point values on the histogram which are saturated to DN values of 0 and 255. This saturation of pixel DN values results in a greater range over which the remaining digital numbers may be expanded.

In image processing, the saturation of digital values is a very significant point, since this practice actually "throws away" reflectance data by converting picture element values to white and black. The losses of these extreme tonal characteristics through saturation have a significant effect on image resolution in urban areas. For example, an analysis on the IMAGE 100 system at the EROS Data Center using a 1:50,000 sub-scene centered over Des Moines, Iowa, demonstrated that when as little as 2 percent of the high-reflectance end of the spectral histogram is saturated to white, many small areas found in the urban scene lose their tonal characteristics. The same

phenomenon was found to be true for the extreme 0.5 percent portion of the histogram saturated to black on band 6. These corresponding picture elements seemed to be related to standing water bodies associated with the Raccoon and Des Moines Rivers. When saturated to black, however, their unique tonal characteristics were lost. These experiences with the IMAGE 100 have led us to take a very cautious view of contrast stretching with saturation of portions of the spectral histogram.

IV. Optronics Film Recorder

The Optronics Photowrite Model P-1500 film recorder is a high-speed digital film-writing system which produces a hard-copy photographic product from digital numbers. The system consists of an unexposed sheet of Kodak Linograph Shellburst 2474 Film clamped to the outside of a circular rotating drum. A beam of light, modulated by the digital information, exposes the film through an optical system consisting of a red light emitting diode (LED) source, an adjustable aperture, and a lens system to focus the light beam onto the film. The drum, film, and optical path are enclosed in a light-proof enclosure which may be removed for developing the film.

As the red-light emitting diode is pulled across a sheet of the Kodak 2474 film, the picture elements are exposed according to the assigned DN value. The negative or positive image produced on the Optronics film recorder (depending upon which playback mode is used) is linearly proportional to the optical image density and digital numbers. In a standard photographic

picture, however, image density is proportional to $\log(E)$, where E (the exposure) is the energy incident on the film. The disadvantage, therefore, of the digitally produced image is that it is not linearly proportional to the scene reflectance or to other photographs.

The density/digital number transfer function for the Optronics P-1500 onto Kodak 2474 film is shown on Figure 8. The Kodak Shellburst film is a thin, mylar-based, high contrast, red-sensitive film. Its dynamic density range is approximately 2.5 optical density units with an associated low fog level of 0.11 to 0.19 density units. The term "fog" is defined as the optical density on a film after development of the silver particles other than those caused by basic exposure. The fog level of the film is important to note since the Optronics film recorder uses a red LED whose intensity is not sufficient to raise a signal above the film's fog level until a DN value of 223 is reached. This suggests that film densities corresponding to DN values of 255 to 223 cannot be differentiated on an Optronics film product. In image processing, this hardware characteristic may be a significant factor in photographically recording high-reflectance data.

V. False-Color Negatives

Before false-color negative printing, the Optronic's black and white positive transparencies must be registered as a set. Since only bands 4, 5, and 7 are normally used for making color composites, band 6 is not registered. The equipment for register-

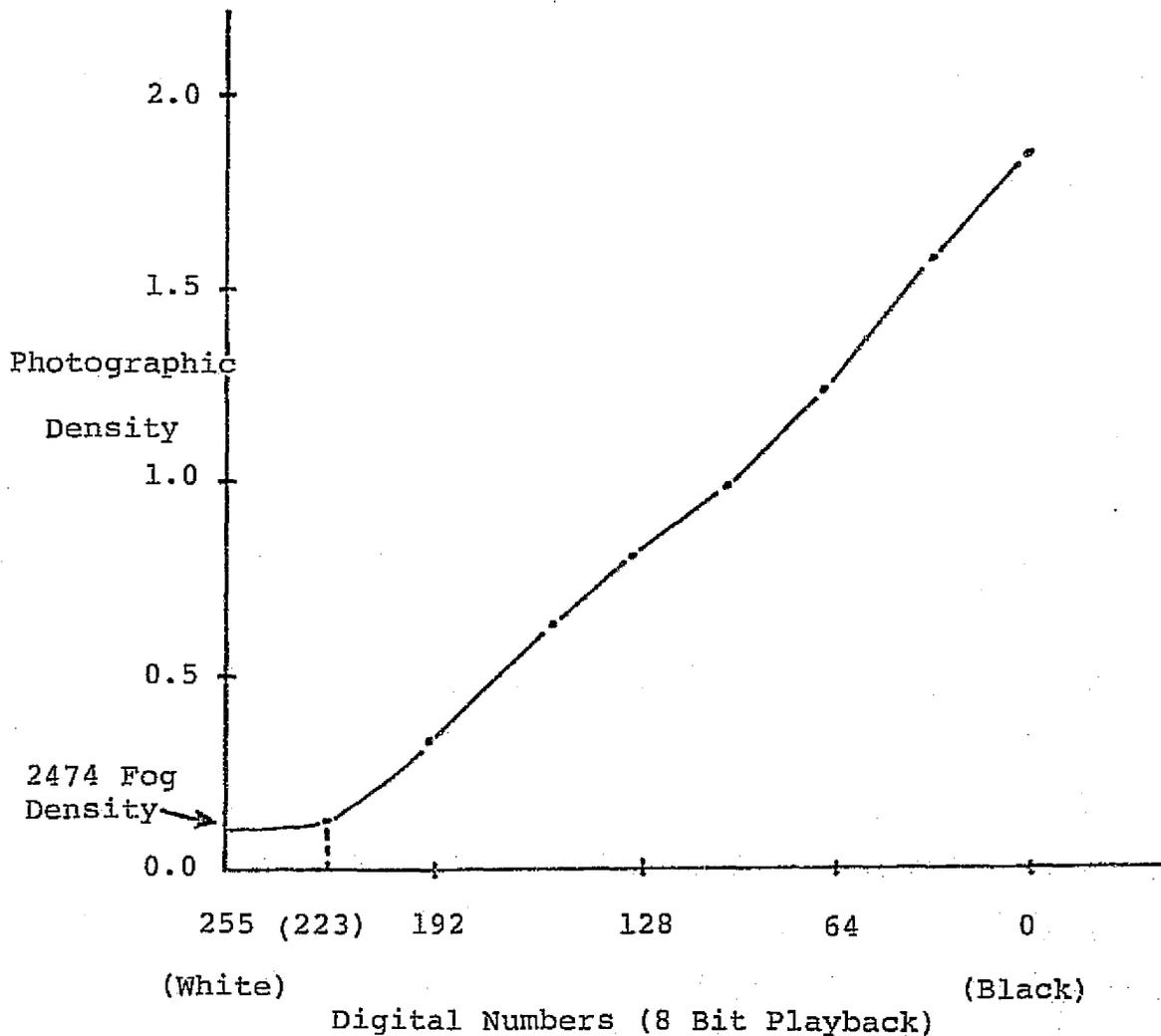
Figure 8

Density / Digital Number Transfer Function for the Optronics
Film Recorder Model P-1500 at the Jet Propulsion Laboratory

Film: Kodak Linograph Shellburst 2474

Optronics Film Recorder (P-1500)

21 August 1974
100 Micron Spacing
Iris = 8.5



Source: A. R. Gillespie
Jet Propulsion Laboratory
Interoffice Memorandum 1-31-75

ing transparencies consists of a light table, registration punch, magnifying eyepiece, and two cross hairs which can be fixed to the light table. The transparencies are individually registered to the fixed cross hairs, punched, and removed from the light table.

The printing of the black and white transparencies onto color negative film is accomplished at JPL by using a contact frame with registration pins mounted on the bed, a point-light source with a filter wheel, three primary filters and filter selector, and a timer for the light source. The first step, however, in producing a false-color negative requires the registration of the MSS band 4 (green spectral band) to the contact frame via the mounting pins on top of a sheet of Kodak 4108 Vericolor II--Type L film. The film and the black and white transparency are exposed for a predetermined time to blue light through a Wratten #47B primary blue filter. Band 4 is removed from the contact frame and is replaced by band 5 (red spectral band) which is registered and exposed to green light through a Wratten #61 green filter. Band 5 is then removed, being replaced by band 7 (infrared spectral band), which is registered and exposed to red light through a Wratten #29 red filter. When this procedure is completed, the exposed Vericolor II film is removed and processed to form a color negative transparency.

The Kodak Vericolor II--Type L film is processed in a Kreonite C-41 roller-transport processor with C-41 chemistry. Five steps are required for development which takes about 20 minutes.

The spectral response, according to Ron Wichelman, JPL Technical Staff Aid to the Photographic Section Manager, of the Vericolor II film should allow the reproduction of all density values recorded on the Optronics' Kodak 2474 film. This statement, however, cannot be documented quantitatively because the exact relationship between the 2474 film's D log E curve and the Optronics' density/digital number curve is not known. The Jet Propulsion Laboratory is presently trying to document this relationship by creating a film product on the Optronics Film Recorder that has densities related to specific digital numbers. These densities, in turn, will be related to the D log E curves for the Vericolor II film.

The Vericolor II color negatives are printed on Kodak RC-37 photographic paper. When the density relationships between the Vericolor II and Kodak 2474 are established, they, in turn, will be related to the RC-37 photographic paper. An assessment can then be made to determine if it is possible to photographically display the complete results of the computer enhanced spectral data on a false-color composite print.

In order to ensure that the false color composites have proper color balance, the three Optronics positives used in the construction of the color negative must be developed to possess similar film gammas. That is, the three positive black-and-white films must have the same linear relationships between image densities and the log of the exposure. The easiest way to ensure that the films have the same gammas is to process the films at the same time under the same conditions. This is

accomplished on a routine basis at JPL, except when hardware problems with the film recorder interrupt the production of a series of images. Unfortunately, if one of three recorded images is not satisfactory, it is not known until the films have been developed. When this happens, the bad bands are rerun and developed separately. This practice potentially produces images which may have different film gammas. If this occurs, it is very difficult to produce a color negative which will record all density values for the three black-and-white films. In summary, the point which must be stressed is that it is imperative for the Optronics products to be processed under consistent, repeatable conditions.

VI. Color Printing at IGS

For land-use interpretation purposes, false-color composites have proved most useful. It is difficult, however, for a photographic technician to know the exposure, color balance, or scale a color print should possess to be optimal for land-use classification purposes. For these reasons, a color photographic laboratory was implemented at the Iowa Geological Survey. To satisfy the photographic needs of the NASA contract, the photo lab had to have the capability of processing both positive color transparencies and color negatives. Subsequently, the Unicolor processing system was identified as the most practical and inexpensive method to meet these capabilities. The initial investment was surprisingly small--about \$115.00. Below is a list with prices for the equipment (beyond the standard black-and-white

photographic paraphernalia) needed for color processing:

1. Unicolor processor drum	\$29.00
2. Color compensating filters	30.00
3. Unicolor drum roller	41.00
4. Unicolor thermometer	15.00
	<hr/>
Total	\$115.00

The color photographic papers which are used at IGS in the Unicolor system are Kodak RC-37 for printing color negatives and Ciba-Geigy Cibachrome Type A for printing color positives. Processing costs per picture (chemical + paper) are listed below:

<u>Photo Paper Type</u>	<u>Print Size</u>	
	<u>8" x 10"</u>	<u>11" x 14"</u>
RC-37	\$ 0.87/print	\$ 1.34
Cibachrome Type A	\$ 1.89	\$ 3.89

Included in this report are examples of IGS color printing. Figures I and II in Appendix A are 11 x 14-inch color composites printed from a JPL Vericolor II negative on Kodak RC-37 photographic paper. Figure III is an 8 x 10-inch Cibachrome print made from a Kodak High Speed Ektachrome 35mm color transparency, while Figure IV is a Cibachrome print taken from an EDC standard-product color transparency. Of these two photographic papers, the Cibachrome Type A has much higher resolution than the Kodak RC-37. Cibachrome photographic paper, unfortunately, can be used only for printing color-positive transparencies. Although Cibachrome Type A has higher resolution, a disadvantage to its use is that its high-gloss surface retains

fingerprints very easily. Care must be taken while handling Cibachrome prints.

The chemical processing cycle for either paper takes about 12 to 15 minutes. Since there are varying processor drum sizes, as many as two 11 x 14-inch prints or four 8 x 10-inch prints may be developed at once if the largest Unicolor drum is used. The chemical temperature requirements for both of these color papers are not extremely critical, $75^{\circ}\text{F} \pm 3^{\circ}\text{F}$ for the Cibachrome chemicals, while the RC-37 paper requires a 5°F range ($72\frac{1}{2}^{\circ}\text{F} \pm 2\frac{1}{2}^{\circ}\text{F}$) for the developer and a 10°F range ($75^{\circ}\text{F} \pm 5^{\circ}\text{F}$) for all other chemicals.

The main point to be made in this discussion on color photography is that high quality prints may be obtained very cheaply by persons with a minimal amount of photographic experience from these available color processing systems. This ability to print color composites allows the image user to:

1. project the prints at the exact desired scale,
2. expose for optimal tonal characteristics (which are based on the types of interpretations required),
3. adjust for suitable color balance, and
4. avoid long waits for commercial color processors to finish contracted jobs.

Concluding Remarks on Image Processing

There are several remarks, based on experience in the execution of this contract, which can be made concerning image processing techniques. These comments are summarized below:

1. Contrast Stretching

The contrast stretching of spectral data across the complete dynamic range should be done in such a manner that no data is "thrown away" by saturating the end portions of the spectral histograms to white (DN = 255) or black (DN = 0). IMAGE 100 analyses indicate that even when very small portions of the spectral histograms are saturated, a noticeable difference in tonal detail can be discerned. This is particularly true for urban scenes where there is a clustering of both high and low reflectance land-cover phenomena.

2. Optronics Film Recorder

The losses of high-reflectance detail in a computer-enhanced scene may also be caused by the limitations in the Optronics film recorder. Since this film recorder's LED cannot raise a signal on the Kodak 2474 film (due to the fog level) above DN value of about 223, the contrast-stretch bounds should probably only span the range of DN = 0 to DN = 223. This should ensure that all contrast levels on the enhanced LANDSAT scene are recorded on the Optronics film.

In addition, the black-and-white film products of the Optronics film recorder must be processed to have equal gammas for their D log E curves. This practice will ensure that color negatives may be constructed that will record all densities found on the three black-and-white Optronics transparencies.

3. Color Photographic Processing

The capability of processing color photographic products

at the Iowa Geological Survey has been an important accomplishment in the execution of this NASA contract. The high quality prints which may be obtained by amateurs in addition to the minimal amounts of time and money required for color photographic processing, support this contention. The ability to print color composites optimizes the use of enhanced LANDSAT imagery for land-use classification purposes.

Image Interpretation of Wapello County, Iowa

I. Geomorphic Setting of Wapello County, Iowa

Wapello County is typical of the eleven-county study area. It possesses a variety of surface topographies which, in turn, influence the area's land-use activities. In the northeastern portion of the county, flat-lying, highly productive agricultural lands are found. The southwestern portion is an area of rolling hills with patches of forest land. The Des Moines River, which cuts diagonally across the county, acts as a rough dividing line for these two topographic regions. In addition to its rural and agricultural base, Wapello County possesses a relatively large (by Iowa standards) urban area, Ottumwa, which has a population of approximately 30,000.

Although any land-use study obviously depends on a knowledge of surface topography, an understanding of the materials which underlie the surface is also necessary. Within Wapello County important relationships exist between the earth materials and their stratigraphic relationships, the landforms associated with these relationships, and the resultant effect on land-use

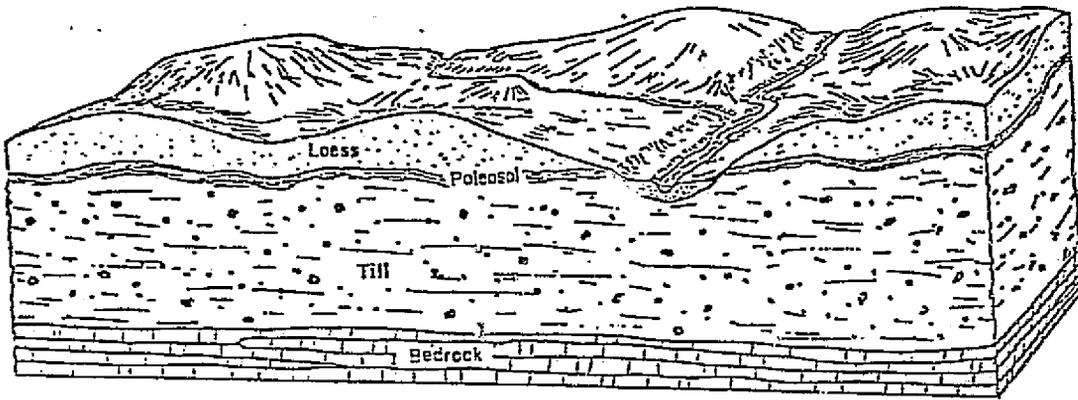
activities. Three dominant landform systems are prevalent throughout the county. These systems are illustrated by the three-dimensional block diagrams found on Figure 9.

The first landscape or geomorphic model shows an area which is dominated by loess or wind-blown silts. The loess upland is generally located along the high and relatively flat stream divides. An example of this terrain is found in the northeastern portion of Wapello, County. Figure I in Appendix A shows a LANDSAT-1 computer-enhanced subscene to Wapello County taken on 15 April 1974. The dark bluish-black hues (labeled L on the overlay to Figure I) correspond to these loess uplands. This topography is generally good agricultural land although it may be poorly drained. The thickness of loess is variable, reaching a maximum of about 10 feet in some places. Below the loess is a buried soil, called a paleosol, which lies on top of the glacial till. The combination of flat terrain and the clay-rich paleosol and glacial till creates some drainage problems in that the downward movement of water is somewhat inhibited.

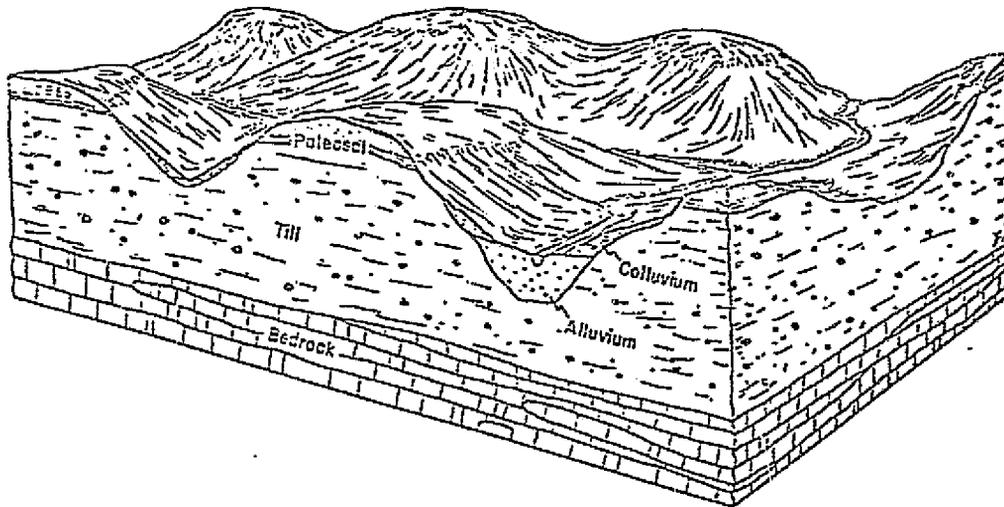
Examples of the second geomorphic model, hills of glacial till, are labeled "T" on the overlay for Figure I. These areas are dominated by hills which are comprised of glacial till. Loess may cap the hills, but buried soils and glacial tills are exposed on the hillsides. Because the physical characteristics of the till make farm management difficult, these areas are less intensively farmed. For this reason, stands of forest in addition to pasture land are frequently encountered in this geomorphic

Geomorphic Models

Model I--Loess Uplands

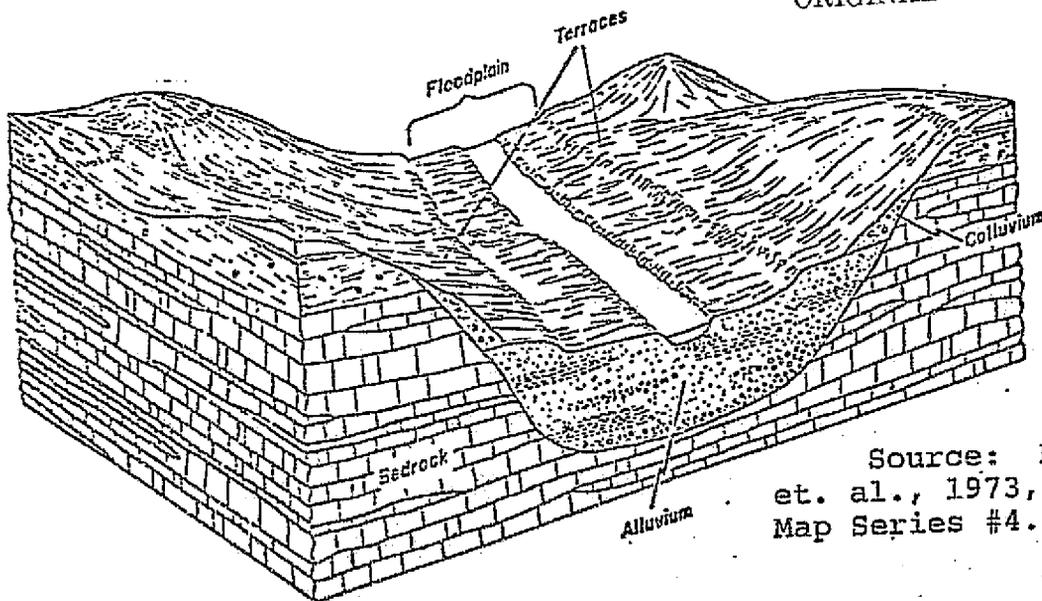


Model II--Hills of Glacial Till



Model III--Valley Complex

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Source: Hoyer, B., et. al., 1973, IGS Misc. Map Series #4.

setting. The overlay to Figure II, which is a LANDSAT-1 computer-enhanced subscene of Wapello County taken 29 August 1972, displays the extent of forest cover present in the county.

The third landscape model illustrates the relationships of the valley complex. These valley areas are very intricate with slope wash deposits (colluvium) on the valley sides and alluvial materials (water-laid) materials on the floodplains. In some places, stream terraces are found on the valley sides, marking the extent of past floodplains before down-cutting of the stream occurred. The earth materials in the valley complex are composed of all textures of materials from clays to sands and gravels. This landscape type is labeled "V" on the overlay for Figure I.

Minor valley systems interrupt the topography of the loess uplands area in northeastern Wapello County, while a major valley system is associated with the Des Moines River. This river valley has an extensive deposit of water-laid materials within its confines. The extent of the river's floodplain is delineated on the overlay to Figure I, being labeled the "Des Moines River Alluvial Valley." Its interpretation was made visually corresponding to the dark-colored hues which relate to saturated alluvial materials.

II. Soils and Agricultural Land-use Interpretations for Wapello County

On the computer-enhanced April scene (Figure I) for Wapello County, Iowa, three distinctly different colored areas are

immediately apparent: (1) a dark area of regularly-spaced roads in the northeastern half of the county (labeled "L" on the overlay to Figure I), (2), the light pink and brown hues which make an irregular pattern in the southwestern half of the image (labeled "T" on the overlay), and (3) the narrow bluish-black strip running diagonally from the northwest to southeast across the county, roughly forming a boundary between the other two areas. Each of these areas is unique geologically, therefore, having different agricultural land-use characteristics.

The area of low reflectance (labeled "L") in northeastern Wapello County, corresponds to a relatively flat upland which is somewhat poorly drained. In terms of the geomorphic models discussed previously, this area is termed "loess uplands." The low reflectance and therefore dark hues in this upland area is a result of black prairie soils, cultivation of fields, and high moisture conditions. Windblown silts, called loess, form the parent material for these highly productive soils. The area is well adapted for intensive farming of row crops, especially corn and soybeans. Fields in this area are generally square, being about 40 acres each. Because of the relatively flat terrain characteristics, roads are spaced regularly on a one-mile grid pattern corresponding to the public-land survey system. Several small upland areas of this landscape type are also found in the southern and western portions of Wapello County.

Stream development has dissected these loess-mantled uplands slightly. On the valley-side slopes down to the streams, row crops (such as corn and soybeans) are commonly found, but pasture and cover crops (alfalfa, etc.) dominate. These valley complex areas, designated "V" on the overlay to Figure I, show many hues of red indicating healthy, green, spring vegetation on this false-color composite. The red hues in the valley complex areas show a marked contrast with the bluish-black hues of the loess upland areas which are characterized at this time of the year by cultivated row-crop fields with high soil moisture conditions.

The area of variegated blue, red, and brown hues in the southwestern half of Wapello County is a hilly region less adapted to intensive agricultural use. This area, labeled "T" on the overlay to Figure I, relates to the third geomorphic model--hills of glacial till--and is characterized by much pastureland, patchy woodland areas, and small irregularly-shaped fields. Small coal strip mines are common as well as one-acre or smaller farm ponds. The hilltops in this region are loess-mantled with the underlying glacial till and associated paleosols being exposed on the hill-sides. This land is subject to severe erosion problems when over-grazed or put into continuous row crops.

The Des Moines River Valley (delineated on the overlay to Figure I) and its associated alluvial materials, cuts diagonally across Wapello County. The bottomland areas are heavily cropped with corn and soybeans. The soils in this alluvial valley have

a highly variable texture, ranging from sandy to clay rich.

The lines superimposed on the April image (Figure I) from the overlay (except those lines delineating the Des Moines River alluvial valley) were transferred directly from the 1921 Soil Survey of Wapello County. Even though the report is out of date in terms of soils names and detail of mapping, the data portrayed on the soils map are useful in analyzing the April LANDSAT image. It should be noted, however, that the lines selected from the 1921 survey were chosen because of their agreement with the color characteristics found on the April composite.

Comparison of the 1921 soil map with modern soil surveys conducted in adjacent counties (Keokuk and Jefferson), along with a knowledge of soil-landscape principles, allows one to determine approximately how the soils on the old map would be classified today. For example, in the 1921 survey, the flat upland area (L) was mapped as the Grundy silt loam and silty clay loam. Today this area would be mapped as several soils: Taintor, Haig, and Mahaska silty clay loams, in addition to the Sperry and Edina silt loams. This area also includes, at least in part, those soils now mapped as Grundy and Otley silty clay loams. Slopes along the drainages in this upland area (labeled "V") were mapped as the Clinton silt loam on the 1921 soil map. Today this same area would probably be classified as the Pershing, Ladoga, and Weller silt loams as well as including some of the Grundy and Otley silty clay loams. The bottomland soil along the

streams in these valleys would have other soil series names which are not differentiated in this discussion.

The hilly land in the southwestern half of Wapello County (T) was mapped as many soils, but dominantly as Clinton silt loam and Lindley loam. Today the association of soils would probably be the Weller silt loam on the hilltops and the Lindley and Keswick loams on the hill slopes. The alluvial soils along the Des Moines River are highly variable and are therefore not differentiated for discussion purposes.

One method of relating the agricultural value of the three areas (L,V, and T) found on the overlay to Figure I is to compare the productivity of the soils based on our assumed modern soil series names. The corn suitability rating (CSR), which is a system utilized by the Iowa State University Agriculture Extension Service and also the U.S. Soil Conservation Service, is used in Iowa to compare the productivity of soils based on actual yield figures. The Muscatine soil series, the most productive in Iowa, is used as the highest standard and is given a productivity value of 100. All other soil series productivity, under good farm management, are compared to this standard. By using the middle value for the range of CSR ratings of the modern soils correlated to be in Wapello County, the average corn suitability rating for each area labeled on the overlay to Figure I was computed. The mean CSR results for these areas are: (1) area L--CSR of 76, (2) area V--CSR of 60, and (3) area T--CSR of 31.

These figures must be accepted as only indicative of the relative productivity of each area. To obtain more than a generalized CSR, a modern soil survey would have to be completed for Wapello County. The area of each soil would be used to weight the mean CSR values. In addition, the corn suitability ratings would have to be regionally standardized.

In summary, these generalized CSR values are indicative of Wapello County's agricultural land-use activities which may be related to the tonal characteristics found on the April image. It should be noted, however, that the previous discussion does not mean to imply that LANDSAT imagery can be used for detailed soil mapping or that this imagery ought to be exclusively applied to mapping agricultural land productivity and capability. It does mean, however, that the April computer-enhanced image is providing useful, generalized information related to agricultural land-use practices which is not provided at other times of the year from LANDSAT images.

III. Land-use Mapping for Wapello County, Iowa

The land-use map for Wapello County, Iowa (overlay to Figure II) was generated by conventional image interpretation techniques from a JPL computer-enhanced MSS scene dated 29 August 1972. The image scale of 1:125,000 for the false composite was chosen to correspond to available Iowa Department of Transportation general highway and transportation maps. These maps provide a uniform

basis in Iowa on which land-use interpretations from LANDSAT images may be applied. Figure 10 is a 1:250,000 scale example of such a map for Wapello County. In addition to the selection of this scale (1:125,000), the print's color balance and exposure were chosen to optimize land-use interpretations. The land-use categories mapped from the LANDSAT scene for Wapello County were: (1) urban, (2) transportation nets, (3) forest land, and (4) water bodies. A discussion of interpretation techniques in regard to these land-use categories follows:

1. Urban

The urban areas in Wapello County are expanses which possess both high- and low-reflectivity characteristics. On the JPL computer-enhanced color composite for August, these areas are represented by blue to bluish-white hues. The darkest blue colors, in Ottumwa for example, are interpreted to correspond to the commercial-industrial parts of the city. In this central urban section, the spectral reflectance from asphalt and concrete dominates the MSS scene. Commercial-industrial buildings, which have tar roofs, are usually found in the older sections of the commercial-industrial district, while newer buildings have roofs constructed from high-reflectance materials which are designed to dissipate heat during the hot summer months. This combination of high- and low-reflectance land-cover gives the commercial-industrial scene its blue to white color on the August color composite. The lighter, variegated blue and red hues surrounding

the commercial-industrial section in Ottumwa correspond to the urban-residential category. Vegetation associated with residential sections is responsible for the slightly different spectral response.

On the land-use overlay for Wapello County, the urban sections are undifferentiated. To subdivide the urban land-use category, a larger scale image is required. An example of such a LANDSAT image is found on Figure III in Appendix A. This scene of Ottumwa was generated on the EROS Data Center's IMAGE 100 system from a CCT dated 29 August 1972. The scene was contrast stretched and displayed on the cathode ray tube (color television screen) at a scale of 1:50,000. B4, G5, and R6 in the right-hand corner of the print refer to the colors assigned to the spectral bands to produce the false-color composite. For example, band 4 is colored blue, band 5 is assigned green, and band 6 is displayed as red. The picture found on Figure III was taken from the IMAGE 100's television screen on Kodak High Speed Ektachrome film. This 35mm color transparency was printed on Cibachrome Type A photographic paper. The overlay to this print shows the extent of commercial-industrial and residential sections of Ottumwa as they can be mapped from this large-scale LANDSAT subscene. Water bodies, quarry/strip mines, and forest land are also delineated on the overlay. To a limited extent, the distribution of railroads and highways/county roads are shown.

The interpretation of the commercial-industrial versus

residential areas on the overlay to Figure III is based on the color characteristics on the IMAGE 100 print. The commercial-industrial areas possess both high- and low-reflectance phenomena--primarily asphalt and concrete. Hues on the color composite range from blue to white for this urban section. The residential areas, however, have vegetation cover (trees and lawns) associated with them which give them a slight pinkish hue when compared to the blue and white colors found in the commercial areas. It is on this subtle color basis that these two urban categories are delineated on the overlay to Figure III. Forest cover is differentiated from fields in a similar manner. Forest land has a darker red hue than agricultural fields or pasture lands. Water bodies are displayed on this false color composite as bluish-black colors. The darkness of these water bodies depends on the amount of sediment present in the water. For example, the color difference between the Des Moines River and the nearby standing bodies of water is attributed to the variations in suspended sediment. The standing bodies of water, which are generally sediment-free because suspended particles have time to settle to the bottom, have a bluish-black hue on the composite, while the flowing river, which is actively carrying suspended material downstream, has a bluish-gray color. Quarry and strip mines are both high-reflectance land-use categories in Wapello County that are mapped on the overlay to Figure III. No differentiation is made between either category.

Some difficulty, however, has been experienced with the interpretation of some aspects of urban land use from computer enhanced LANDSAT imagery. For example, on the color composite of Wapello County for August (Figure II) categories such as urban, quarry/strip mines, and agricultural land, in some place or another, seem to have the same blue-color characteristic which make their differentiation or interpretation, based solely on color, difficult or impossible. The reason for this blue-color saturation being common to so many diverse land-use features is not presently understood. Efforts to isolate the cause of this problem are being made by experimentation with different image processing and photographic techniques.

2. Transportation Networks in Wapello County

The August 29, 1972 scene for Wapello County vividly displays the existing road network. In August, a virtual canopy of vegetation exists across the county, being interrupted only by cultural developments such as town, strip mines, or roads. The roads, however, are high-reflectance phenomena in comparison to the surrounding vegetation cover and are therefore easy to differentiate. Railroad lines, on the other hand, are more difficult to delineate since they are narrower and sometimes lack high reflectance roadbeds. Many of these railroad right-of-ways are relatively old cultural features. Attendant land-use activities have accordingly developed around the lines which, in turn, make it possible in some places to trace railroad

routes across the landscape by noting the changes in land-use. Railroads also do not generally follow the public land survey boundaries as most of the Iowa roads do. The color characteristics of the rail lines on the August composite vary between white and bluish-green. They always seem to be less pronounced than roadways. In some places, railroad lines cannot be differentiated.

3. Forest Land

The forest land areas in Wapello County are related to those lands which are less intensively used for agricultural purposes. The dot pattern on the overlay to Figure II shows the extent of forest cover existing in the county during August 1972. The interpretation of the forest land from LANDSAT imagery is based on the dark-red color characteristic which differs from the lighter hue or red which characterizes vegetated agricultural lands. Although upland and bottomland forest species are not differentiated on the land-use overlay, it may be possible to subdivide the forest land category into these two groups from the color variations within the forest areas. The bottomland forest species seem to be characterized by a darker (reddish-black) hue which relates to valley bottom drainage paths. The upland trees, which are found on the valleysides and hilltops, have a bright red color on the image which is common to healthy-growing stands of trees. It must be stressed, however, that this interpretation of forest land groups is tentative. Field checking

remains to be conducted in order to verify the existence of these possible forest land categories based on spectral reflectance characteristics.

4. Water

The water bodies in Wapello County are related either to alluvial systems, such as the Des Moines River, or to man-made ponds found on farms or in abandoned strip mines or quarries. The spectral reflectance characteristics of these water bodies relate directly to the clarity of the water. The Des Moines River, which is actively carrying sediment, has a bluish-green hue on Figure II. The associated ox-bow lakes near Ottumwa, however, have an almost black color which is attributed to the lack of sediment present in the water. This bluish-black color is also a characteristic of most man-made ponds except where they are polluted or supporting abundant algae growths. On the land-use overlay to Figure II, water bodies were mapped that were generally larger than five acres. The numerous smaller ponds of the county, therefore, are not differentiated. The extent of water in the Des Moines River channel is also recorded on the overlay.

Comparison of the August Computer-Enhanced Scene to an EROS Data Center Standard Product

Figure IV in Appendix A is a 1:125,000 scale color-composite print of Wapello County, Iowa made from an EDC 29 August 1972 standard-product color transparency. When this print is compared

to its computer-enhanced counterpart (Figure II), the difference is most striking. The standard product print has far less detail than the computer-enhanced picture, even though the standard product was printed on a higher resolution photographic paper (Cibachrome Type A). Although no attempt was made to generate a detailed land-use map from the standard product image, it is believed that such a land-use map would be far inferior to the one produced as the overlay to Figure II. This comparison of a Jet Propulsion Laboratory computer-enhanced image versus an EROS Data Center standard product LANDSAT scene helps to demonstrate the effectiveness of image processing techniques for land-use interpretation purposes.

Conclusions to Image Interpretation of Wapello County, Iowa

The conclusions regarding image interpretation of land-use categories for Wapello County, Iowa are found below:

1. The Jet Propulsion Laboratory's computer-enhanced images are judged to be far superior for land-use interpretation purposes than the EROS Data Center's standard product.
2. Land-use interpretations for (1) urban extent, (2) transportation nets, (3) forest cover, and (4) water bodies are better served by the 29 August 1972 computer-enhanced scene than by the 15 April 1974 image.
3. The 15 April 1974 scene effectively portrays characteristics of soils, topography, and attendant agricultural land-use activities which are not readily apparent on LANDSAT imagery

for other times of the year.

4. The land-use of urban areas from LANDSAT imagery in Iowa is most easily interpreted from large-scale subscenes in which individual picture elements can be discerned.

Future Research Plans

I. A trip to the Jet Propulsion Laboratory is planned for early February 1976 to discuss the research strategy for the remaining image processing to be completed to satisfy the NASA contract specifications. At this time decisions will also be made regarding the format and content of the final report which is scheduled for completion during July 1976.

II. Work sessions on the EROS Data Center's IMAGE 100 system are planned to further determine the effects of contrast-stretching and saturation of histogram end portions on LANDSAT image interpretation.

III. The preliminary evaluation of the land-use overlays for the two computer-enhanced images for Wapello County will be completed during the next quarter by the personnel in the Area XV Regional Planning Commission, which is under the direction of Mr. Bruce Bullamore. These results will be utilized in determining which image processing techniques best serve the needs of this planning group. This information will help determine the strategy for future image enhancement at the Jet Propulsion Laboratory.

IV. Color composites for Wapello County, which utilize both

a Gaussian and ramp-CDF contrast stretch for the 15 April 1974 and 29 August 1972 scenes, will be compared to the linear contrast stretched scenes for Wapello County to determine which image-enhancement technique is the most effective for land-use interpretation purposes.

V. Efforts are also being made to determine the photographic relationships between the Optronics Photowrite Recorder's film, Kodak Vericolor--Type L film, and the Kodak RC-37 photographic paper.

Funds Expended

Table I summarizes the budget allotted by NASA and the funds expended in execution of contract NAS5-20832. The total funds expended by IGSRSL during the first three quarters are \$13,050.91. The Iowa Geological Survey Remote Sensing Laboratory has been reimbursed for the total amount by the government.

TABLE I
BUDGET ALLOTTED BY NASA AND FUNDS EXPENDED BY IGSRSLS

Contract NAS5-20832

Land Classification of South-Central Iowa from Computer Enhanced Images

Contractor:

Iowa Geological Survey Remote Sensing Laboratory (IGSRSL)
Iowa Geological Survey
123 North Capitol Street
Iowa City, Iowa 52242

<u>Element of cost</u>	<u>Budget Allotted by NASA</u>	<u>Expended Funds by IGSRSLS to Date</u>
Salary for Project Manager Based on 16 Months	\$16,874.00	\$9,112.00
Employee Benefits for Project Manager	2,038.00	966.75
Travel Related to Project-Transportation	2,400.00	1,096.40
-Per Diem	1,600.00	783.92
Expendable Materials and Photographic Supplies	863.00	491.14
Publication Expense	5,000.00	600.70
Subtotal	\$28,775.00	\$13,050.91

Funding to the Jet Propulsion Laboratory (JPL) by NASA

Salary for JPL Scientific and Technical Staff and Computer Processing Time	20,000.00	Billed to NASA by JPL directly
Total Funding by NASA for Contract NAS5-20832	\$48,775.00	

Payments Received to date by IGSRSLS from Government..... \$13,050.91

Appendix A