E7.3 10679
CR-132186

Type II Progress Report

Period ended May 31, 1973

a - Title - ERTS Data User #119 - Effective Use of ERTS Multisensor Data in the Great Plains

b - Principal Investigator number - Victor I. Myers UN-642

c - Problems impeding progress -

Visual appraisal of ERTS color composites shows that differences in range vegetation are more difficult to distinguish after the "brown-up" stage has been passed in the summer. Imagery over the range study sites has been obtained subsequent to early September. It is anticipated that imagery obtained in June and July, 1973, will be much more valuable for analysis than that which is now available.

d - Accomplishments

1. Rangeland (Dr. Lewis, Investigator)

(a) Photo interpretation of color composite images of the test area has indicated that differences in range plant communities within soil delineations are difficult to distinguish after the "brown-up" stage.

2. Cropland (Dr. Horton, Investigator)

(a) K-class classification was performed on the two mile by nine mile Centerville study area, ERTS frame no. 1023-16440, August 15, 1972, using bands 5 and 6. The location of the study area is shown in figure 1.

(b) The training samples used in the K-class analysis consisted of 192 data points from three corn fields, 128 data points from two soybean fields, and 128 data points from two fallow fields. (The distribution of the training set data in bands 5 and 6 is shown in figures 2 and 3 of the Type I Progress Report for the period ended March 31, 1973.)

(c) A computer generated K-class map was printed out, and the actual field boundaries in the study area, determined by using C-47 imagery, were drawn on the map in their spatially correct positions. Figure 2 shows a portion of the K-class map with sketched-in field boundaries. The percent correct classification for each class was then determined.

(E73-10679) ERTS DATA USER NO. 119: EFFECTIVE USE OF ERTS MULTISENSOR DATA IN THE GREAT PLAINS. ERTS-1 MSS IMAGERY: A TOOL FOR (South Dakota State Univ.) 38 p HC $4.00 CSCL 08M
N73-25374
Unclas
G3/13 00679

39 pp

3. Land Systems (Dr. Westin, Investigator)

   (a) Dr. Westin is presently in Germany, presenting a paper on the use of ERTS imagery to the General Assembly of Committee on Space Research (COSPAR). A copy of his paper is attached and made a part of this report. Information concerning land systems for this reporting period will be found in the attachment.

4. Data Analysis

   (a) See comments in paragraph 2 above.

e - Significant results

1. Cropland (Dr. Horton, Investigator)

K-class results are shown in tables 1 and 2. The percent correct classification was 62.4 corn, 69.2 for soybeans, 41.7 for fallow, and 42.3 for "other". (1 and 2).

Table 2 shows that 19.8 percent of corn was incorrectly classified as soybeans, and 21.3 percent of soybeans was incorrectly classified as corn. However, when K-class classification was performed on the training set data (refer to table 1., Type I Progress Report for the period ended March 31, 1973), 93.75 total correct classification of corn, soybeans, and fallow was achieved. It is probable that the small number of training set data points did not account for much of the variability in the corn and soybeans in the study area. Therefore less accurate classification of corn and soybeans was achieved than the classification results of the training set data indicated.

Much of the variability in corn and in soybeans can be traced to differences in stages of maturity resulting from a wider than normal range of planting dates because of excess amounts of precipitation in May, 1972. The total precipitation was 7.54 inches compared to a 30 year average of 3.48 inches. Normally, corn planting begins the first week in May and is nearly completed by the first week in June. Soybean planting usually begins about mid-May and is generally completed by the second week in June. Because of the wet conditions in

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1. Serreyn, David and Gerald Nelson, "The K-class Classifier", SDSU-RSI-73-08. Remote Sensing Institute, South Dakota State University, Brookings, South Dakota 57007.

2. Kaveriappa, G. K. and Gerald Nelson, "Unsupervised Iterative Clustering in Pattern Recognition", SDSU-RSI-73-08. Remote Sensing Institute, South Dakota State University, Brookings, South Dakota.

the middle and latter parts of May, some of the corn and soybean planting was delayed. The delay in planting of some of the corn and soybeans resulted in greater than normal variations in stages of maturity of the corn and soybeans on August 15, the date of ERTS frame no. 1023-16440 used in the analysis.

Fallow proved difficult to recognize. The primary reason was that many of the fields classified as fallow in the original ground truth survey in early July were partially covered with vegetation (weeds) on August 15. Those fields where a bare soil operation was maintained were correctly classified. Those fields with weeds were generally classified as "other".

All cover except corn, soybeans, and fallow was considered "other". Grassland, trees, and small grain stubble comprised most of this class. Table 2 shows that 30.5 percent of "other" was misclassified as corn, and 17.1 percent of "other" was misclassified as soybeans. In band 6, most of the "other" fell within the same output code range of 41-142 as corn, soybeans, and fallows. (See figure 3 of the Type I Progress Report for the period ended March 31, 1973.) Therefore much of the "other" was misclassified using bands 5 and 6.

2. Land Systems (Dr. Westin, Investigator)

See Attachment

f - <u>Published Articles</u>

ERTS-1 MSS Imagery: A Tool For Identifying Soil Associations, by Dr. Frederick C. Westin. Prepared for presentation at the ERTS-1 session of the Symposium on Approaches to Earth Survey Problems Through the Use of Space Techniques, General Assembly of Committee on Space Research (COSPAR), Konstanz, West Germany, May 23-25, 1973.

g - <u>Recommendations</u>

None

h - <u>Changes in Standing Order Forms</u>

None

i - <u>Image Description Forms</u>

See enclosure 1.

j - <u>Data Request Forms</u>

None

k - <u>Other Information</u>

1. Objective of contract - same.

2. Summary of Work Performed -

a. Rangeland

Selected mapping units were delineated on aerial photography of the ERTS rangeland site. In early August and again near the time of satellite overpass 3 in early September, vertical and oblique 35 mm stereograms were taken using flash illumination with high speed Ektachrome film of three to six 0.25 meter square plots randomly selected within each mapping unit. A subsample of the plots was clipped and vacuumed; and herbage standing crop by species and wild study crop was determined in the laboratory. Observations were recorded concerning surface soil water, bare ground and stage of maturity of the vegetation. Oblique stereograms were made in two directions at ¼ mile intervals along the center of the test sites within two days of the time of overpass 2 in early August.

Fourteen channel multispectral imagery was obtained on all test locations using the Michigan C-47 aircraft on July 24, 1972. Black and white film with red and infrared filters, Ektachrome and Ektachrome IR film were used on the same date using Hasselblad cameras in RSI aircraft. RB-57 flights made in early June and mid September.

Range vegetation maps compiled by various federal agencies are being assembled.

Portions of 35 mm stereograms of known plant materials were digitized and out-put maps produced using the K-class classifier and a mode-seeking program with data from only one vegetation group or from three vegetation groups. The mode-seeking program using only one vegetation group gave the best out-put map. However, consistent misclassification resulted from failures to separate images with similar transmission values in somewhat different wave lengths.

Color composites of ERTS imagery from pass 3 (early September) and pass 5 (early October) have been studied.

Differences in vegetation were more difficult to detect after brown-up in October, even though some brown-up had already occurred at the time of pass 3.

b. Cropland

Portions of bands 4-7 positive transparencies of ERTS frame no. 1023-16440, August 15, 1972, containing the Centerville study area were digitized at a resolution of 36 points per mm.

Training samples consisting of 192 points from three corn fields, 128 points from two soybean fields, and 128 points from two fallow fields were selected in the study area. (The distribution of the training set data in the four ERTS bands is shown in figures 1-4 of the Type I Progress Report for the period ended March 31, 1973.)

K-class classification was performed on the training set data. The highest percent total correct classification (93.75) was achieved using bands 5 and 6. (Refer to table 1 of the Type I Progress Report for the period ended March 31, 1973.)

The training set data in band 6 was further analyzed using a mode seeking program. Using mode seeking, 99.5 percent total correct classification of the training set data was achieved. (See paragraph c under Accomplishments and paragraph g under Significant Results of the Type I Progress Report for the period ended March 31, 1973.)

K-class classification was performed on the entire study area. Using bands 5 and 6, the percent correct classification was 62.4 for corn, 69.2 for soybeans, 41.7 for fallow, and 42.3 for "other". (Refer to the Significant Results section of this report for further details.)

c. Land Systems

See Attachment and previous reports.

3. Conformance - All work to date has conformed to contract work schedule.

4. Analyses of work progress - Satisfactory.

5. Efforts to achieve reliability - These efforts are continuing by utilization of various data analysis techniques previously mentioned and by comparison with known ground truth data.

6. Adequacy of funds - Adequate

7. Significant changes in contractors personnel - None.

8. Planned work:

a. Rangeland

Selected portions of the multispectral scanner data obtained with the Michigan C-47 aircraft are being digitized and will be analyzed. Special attention will be given to ratios of different bands. Seventy mm chips of selected ERTS frames will be requested from pass 2 (late August), pass 3 (early September), pass 5 (early October), pass 9 (late December) and pass 15 (early April). These chips will be analyzed with the I^2S system preliminary to further work. Areas have been selected on specific ERTS frames for 1:60,000 enlargements.

Areas with known ground truth will be extrapolated using aerial photography and compared with ERTS imagery using photo interpretation techniques and machine classification.

Since all of the ERTS imagery from 1972 was obtained late in the season, particular attention is being paid to imagery received after green-up in 1973. Ground truth data have been collected at the Cottonwood Range and Livestock Experiment Station at each ERTS pass since mid-March. Underflight of the ERTS pass on June 22, 1973 is planned with the RSI aircraft accompanied by extensive ground truth collection. RB-57 coverage has been requested for late June or very early July.

b. Cropland

Further analysis of the August 15 data will be conducted using a mode seeking program to attempt to correlate the data distributions in bands 5 and 6 with variations in stages of maturity in the corn and soybeans.

September 2 imagery will be analyzed in a manner similar to the analysis conducted on the August 15 imagery with particular attention paid to the influence of stage of maturity on the "signatures" of corn and soybeans in all four ERTS bands.

Imagery for various points in the 1973 growing season will be analyzed using temporal data to assist in the identification of small grains, crop, and soybeans.

Classification of crops will be extended to a county-wide basis for some particular point in the 1973 growing season.

c. Land Systems

See Attachment

d. Data Analysis

The plan for the month of June 1973, is to work on boundary detection algorithms. These include the Roberts-Gradient (3) and dynamic programming (4) algorithms. The application of these algorithms is to detect the boundaries of lakes.

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3. Rosenfeld, A. and M. Thurston, "Edge and Curve Detection for Visual Scene Analysis", IEEE Transactions on Computers, Vol. C-20, No. 5, pp 562-569, May 1971.

4. Montanari, U., "On the Optimal Detection of Curves in Noisy Pictures", Communications of the ACM, Vol. 14, pp 335-345, May 1971.

Figure 1. A band 5 negative print of a portion of ERTS frame no. 1041-16435, September 2, 1972 showing the location of the Centerville study area. Scale 1:400,000.

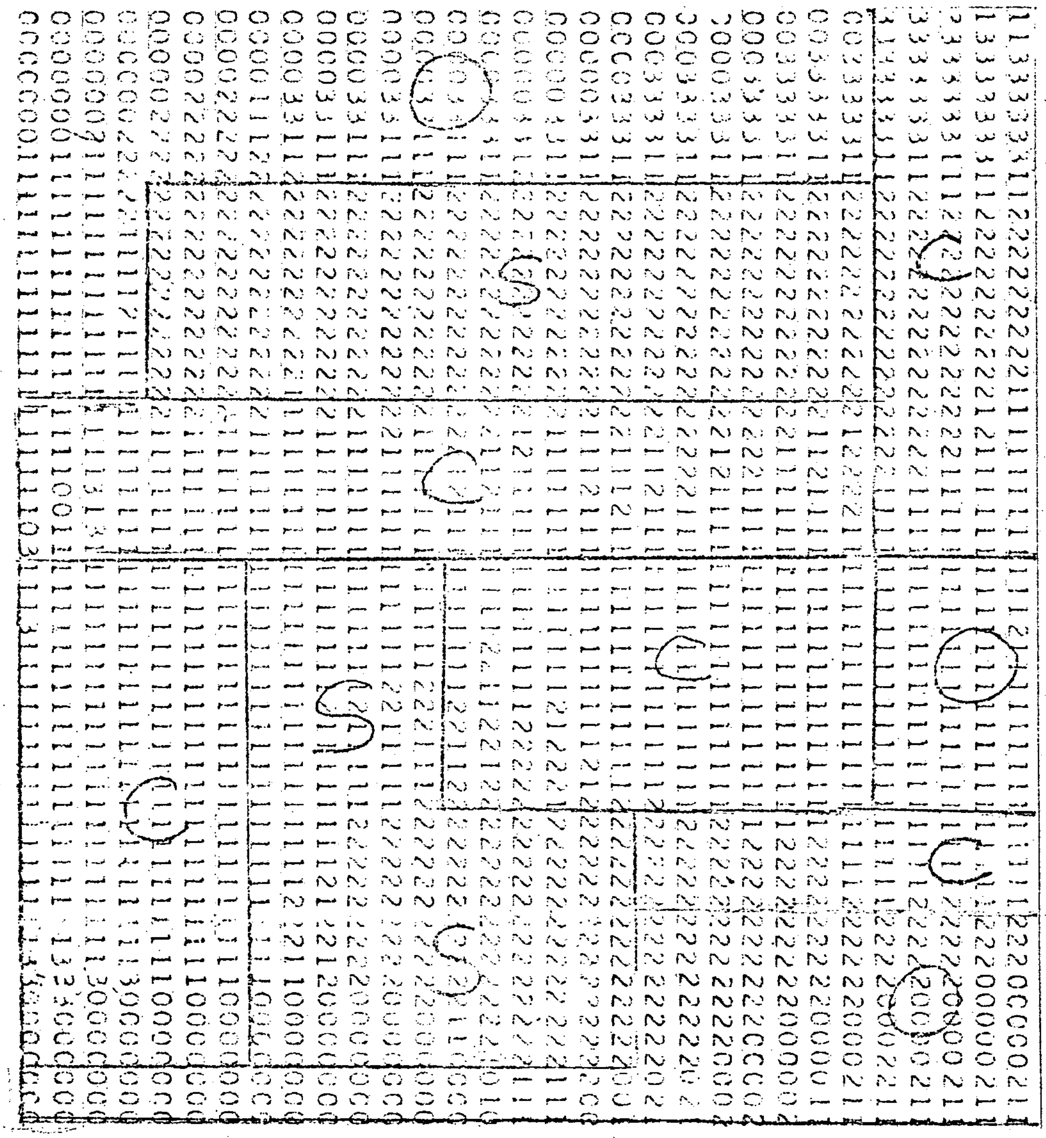

Figure 2. A portion of the K-class map with sketched in field boundaries.

Legend:

Crop	Symbol	K-class code
corn	C	1
soybeans	S	2
fallow	F	3
other	O	0

TABLE 1. K-CLASS CONFUSION MATRIX
BANDS 5 AND 6

Recognition signature	No. of points	Percent	Corn	Soybeans	Fallow	Other
CORN	13,245	62.4	8,267	2,629	931	1,418
SOYBEANS	8,939	69.2	1,903	6,173	69	794
FALLOW	2,410	41.7	264	101	1,006	1,039
OTHER	25,265	42.3	7,701	4,322	2,543	10,699

TABLE 2. K-CLASS RESULTS EXPRESSED AS A PERCENTAGE

Recognition signature	No. of points	Percent correct classification	Percent of class assigned to recognition signature: Corn	Soybeans	Fallow	Other
CORN	13,245	62.4	62.4	19.8	7.0	10.8
SOYBEANS	8,939	69.2	21.3	69.2	0.7	8.8
FALLOW	2,410	41.7	10.9	4.2	41.7	43.2
OTHER	25,265	42.3	30.5	17.1	10.1	42.3

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D
N
ID

DATE May 31, 1973

PRINCIPAL INVESTIGATOR James K. Lewis

GSFC

ORGANIZATION Remote Sensing Institute, SDSU
Brookings, South Dakota 57006

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
1009-11055M				Agriculture
1045-17060M				Alfalfa
1027-17060M				Badlands
1081-17061M				Cropland
1063-17060M				Dendritic drainage
1135-17065M				Dormant Vegetation
1171-17063M				Erosion
1009-17055M				Fallow field
1225-17071M				Forest
1261-17071M				Grass
1027-17061M				Grassland
1045-17063M				Grazing land
1081-17064M				Mature vegetation
1063-17062M				Pasture
1135-17072M				Plowed field
1171-17065M				Prairie
1009-17061M				Rangeland
1225-17073M				Snow
1243-17074M				Soil
1261-17073M				Steppe
1152-17015M				Vegetation
1188-17014M				
1098-17014M				
1224-17021M				
1242-17022M				

These descriptions apply to each product except for variations in cloud cover, seasonal changes (mature or dormant vegetation, or snow) and different geographical areas in western South Dakota (bandlands and forest).

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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Enclosure #1

COSPAR A.5.3

ERTS-1 MSS Imagery: A Tool for Identifying Soil Associations[1/]

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ABSTRACT

Soil association maps show the spatial relationships of land units developed in unique climatic, geologic, and topographic environments, and having characteristic slopes, soil depths, textures, available water capacities, permeabilities, and the like. From these characteristics of the soil broad interpretations can be made such as how the soil is suited for various agronomic and engineering uses. ERTS-1 imagery was found to be a useful tool in the identification of soil associations since it provides a synoptic view of an 8 million acre scene, which is large enough so that the effect can be seen on soils of climate, topography, and geology. A regional view also allows soil associations to be observed over most, if not all, of their extent. This aids in selecting typical sampling sites and provides a check on the homogeniety of the associations. ERTS-1 MSS imagery also provides four spectral bands taken every 18 days which give data on relief, hydrology and vegetation, all of which bear on the delineation and interpretation of soil associations. Enlarged prints derived from the individual spectral bands and shown in gray tones were useful for identifying soil associations.

[1/]SDSU-RSI J-73-03. Supported in part by contract No. NAS-5-21774. Authorized for publication as Journal Series 1189, South Dakota Agricultural Experiment Station, South Dakota State University, Brookings, South Dakota

Preprint prepared for presentation at the ERTS-1 session of the Symposium on Approaches to Earth Survey Problems Through the Use of Space Techniques, General Assembly of Committee on Space Research (COSPAR), Konstanz, West Germany, May 23-25, 1973.

INTRODUCTION

Soil maps are an integral part of an effective agricultural research and advisory program. Soil maps are used for farm and ranch planning, for crop and grass yield estimates, for land use planning, for irrigation planning, for drainage planning, for assessing potentialities for special crops, for rural zoning, and for forest management.

Soil maps are of different scales ranging usually from 1:15,840 to 1:7,000,000. The large scale maps necessary for detailed land planning show the extent of individual soils, and are made by boring holes and walking over the land so that delineations are observed over their entire extent. These soil survey maps are expensive to make and publish.

Small scale soil maps, called soil association maps, are geographic associations of one or several soils and usually are at scales of 1:500,000 to 1:1,000,000. Simonson (1971) states that each soil association consists of a set of geographic bodies that are segments of the soil mantle covering the land surface. Soil associations may include like or unlike soils linked together by mode of occurrence rather than degree of similarity. Field checking of soil association maps is done at infrequent intervals depending upon the scale and use of the map. Although soil association maps of small scale are not as precise for interpretations as detailed soil maps of large scale, they cost much less to make and they do have use for broad planning purposes and for education.

It should be emphasized that the soils shown on soil maps are not defined in terms of profiles alone. According to the soil survey staff of the USDA (1951), each soil unit is a particular kind of landscape and it is these landscapes of soils that are classified and shown on soil association maps. Although soil profiles cannot be seen on air or satellite imagery, soil landscapes are visible. In this regard it should be stated that soil survey experience is necessary if maximum use is to be made of ERTS-1 MSS imagery for identifying soil associations. Soil landscapes exhibit a characteristic surface geometry such as relative frequency of streams, and a characteristic surface composition such as the percentage of bare soil areas. Other features used in differentiating soil landscapes include vegetation and hydrology.

Aerial photographs have been widely used to differentiate soil association landscapes for 40 years. The bulk of these photographs have been black and white panchromatic prints although color and infrared materials have had some use. The aircraft has been the primary platform for obtaining these images. Now, since the summer of 1972, ERTS-1 MSS satellite imagery available in 4 spectral bands and at 18 day intervals brings a new tool to the study of soil association landscapes. It is the purpose of this paper to report on some results using ERTS-1 MSS imagery to identify soil associations.

PROCEDURE

The ERTS-1 multispectral scanner records the electromagnetic energy that comes from features on the earth's surface.

The radiation is in four bands as follows: band 4 - 0.5-0.6 um; band 5 - 0.6-0.7 um; band 6 - 0.7-0.8 um; and band 7 0.8-1.1 um. The spectral energy coming from a soil or crop or other feature depends on its molecular composition. Consequently the various earth's features exhibit unique tonal signatures on the different bands. Tonal signatures can result from multiband viewing or from monochromatic prints derived from one spectral band and shown in gray tones.

The ERTS-1 imagery used for this study consisted of 9 inch transparencies at a scale of 1:1,000,000. From these transparencies three kinds of images were prepared for study: 1) color transparency composites at 1:1,000,000 scale made from bands 4, 5, and 7. These were viewed over a light table with about 3 power magnification; 2) monochrome transparencies of individual bands from which enlargement negative prints of scale 1:500,000, 1:250,000, 1:100,000 and 1:60,000 were prepared. These are the prints used in all figures of this paper except 7 and 8; 3) diazo transparencies of each of the 4 bands were prepared in different colors and also each of them was prepared in black diazo. Black diazo transparency enlargements were used in figures 7 and 8.

In this study an effort was made to study ERTS-1 imagery using equipment usually available to a soil survey office. This consists mainly of access to a darkroom with a good enlarger having a non-diffuse light source. A diffuse light enlarger tends to blend and smooth out boundaries on the images which is not desired. A densitometer was used to quantify some data for figure 8 but the reflectance differences of the bands used are apparent to the eye and use of the densitometer is not required to differentiate the crops shown in the figure.

RESULTS

The results of this study are shown in nine figures. The imagery shown in these figures is all monochromatic derived from the individual spectral bands and shown in gray scale. One of the considerations here is the cost of reproducing color in a publication. These monochrome images were sharp and were enlarged to scales of 1:500,000 and 1:250,000 and even to 1:100,000 without deteriorating to any great extent. One enlargement from a diazo transparency to 1:60,000 is shown in figure 7. Colvocoresses and McEwen (1973) indicate that MSS bulk images have good spectral consistency and good object detectability at a maximum printing scale of 1:250,000.

The ERTS frames each cover over 8 million acres and an advantage of this for use in soil association identification is that it encourages a regional view. Soil associations can be observed over much or all of their area of extent on a scene of this magnitude. Since soil associations occur in repeating patterns, the delineations in general can be observed to see if a change in land use, slope, drainage pattern, hydrology or other feature has changed. A regional view is useful in another way to the soil scientist in that it encourages a regional approach to soil problems. This may ease state line soil correlation problems.

The earth's surface is curved and cannot be shown in a flat map without some distortion. Colvocoresses and McEwen (1973) state, however, that the MSS ray is always within 5.78° of the nominal vertical and the curvature of the earth across one MSS scene is less than 2° so that the image approximates an orthographic view. This means that the reflection on the imagery of the soils, vegetation and other features has a minimum distortion and reflectance measurements can be reasonably quantitative.

ERTS images afford a near real-time view of the scene so that the current use of soil associations can be studied. Comparisons of reflectances of the different bands keyed to ground truth identification provide a means for study of the use of the soil associations.

Climate is one of the factors of soil formation. Figure 1 shows the appearance of soil associations on two bands over a climatic range. The soils on these three scenes are classified as follows: Hapludolls and Haplaquolls dominate in Iowa; in Central South Dakota the fields in cultivation are Haplustolls while the rangeland soils generally have more slope and are dominantly Camborthids; in Western South Dakota the soils are mostly Haplustolls on the flat areas and Torriorthents in the slopes. The ERTS scenes shown illustrate these broad soil patterns in two ways - field size and land use. In Iowa field size is relatively small - 40 to 80 acres, principally. In Central South Dakota field size is 80 to 160 acres or even larger. In Western South Dakota field size is large but the pattern may be one of alternate strips of wheat and fallow. In Iowa the dark tones of Band 7 indicate growing crops over most of the scene at this late summer date. These crops are corn and soybeans primarily with some alfalfa and pasture. This field size and crop pattern indicates a humid climate. In Central South Dakota the white squares on band 7 are fallow fields (indicating a semiarid climate) while the dark fields are wheat or milo. Also in this area only about half of the soils are under cultivation. Band 7 for the western scene shows fallow fields, wheat fields and alternate wheat fallow strips where the soils are cultivated. However, in this area most of the soils are in rangeland indicating an arid climate. The band 5 print for each of the three climatic scenes provides additional information to the soil scientist. Roads and towns stand out on this band. Also more information on crops can be deduced by comparing band 5 with 7. For example, ground truth studies have shown that on band 7 both wheat and milo have high reflectance in the Central South Dakota scene. By comparing the high reflectance fields (dark tones on these negative prints) of band 7 with 5, the milo fields can be separated from the wheat fields since milo has low reflectance and wheat high reflectance on the 5 band. This point is discussed again and illustrated in figure 8. Thus, in an area where agriculture has been carried on for some time the field size and crop pattern appear to give reliable correlations with broad soil associations, and these relationships are visible on ERTS-1 images.

In figure 2 two bands of an ERTS-1 scene are compared with the United States Geological Survey topographic map. The intent here was to determine if a prominent relief feature (in this case the steep-sided northeast-facing Prairie Coteau) could be differentiated. This steeply-sloping glacial area is mainly in grass with deciduous trees, principally basswood, growing in the deeply incised valleys. Figure 2 shows that in band 5 the reflectances of the trees is less than that of the adjacent grasslands and so the areas in trees are clearly delineated as lighter-toned patches. However the reflectances of the grass vegetation on the steep slope is not delineated. On band 7 the reflectances of the trees and grass are similar and the trees and grass together have a lower reflectance than the adjacent farmland and so this area stands out as a dark, wide band. The soils on this steep slope are thinner, stonier versions of the soils being farmed on leveler slopes and are classed as Entic Haploborolls compared to Typic Haploborolls and Typic Argiborolls on the adjacent areas. These thin, steep, stony soils are in grass and trees because this is the most intensive use possible. Although the soil profiles cannot be seen on the ERTS-1 images, deductions concerning their characteristics can be made.

In figures 3, 4, and 5 two bands of an ERTS 1 image are compared with the South Dakota Soil Association Map of Westin and Bannister (1971). Figure 3 is of the western South Dakota Cretaceous plain and is typical of the drier parts of the Great Plains. In table 1 the characteristics and interpretations of some of the soils shown on figure 3 are listed. This soil information is from the South Dakota Cooperative Soil Survey data store and illustrates the kind of information that can be prepared for small scale soil association maps.

A comparison of the soil map with the ERTS-1 prints in figure 3 illustrates that the steep land - number 50, Samsil association (thin, shale-derived Torriorthents) can be accurately delineated. Also the bottomland - 62, Glenberg association (alluvium-derived Torrifluvents) is easily visible. The ERTS prints also show that the Glenberg soil delineation actually is narrower than it is shown to be on the soil map. The other two main soil associations - the upland and terraces - are not as easy to differentiate from each other although they stand out from the Samsil and Glenberg associations. Number 32, the Ralph association, (soft silty shale-

COSPAR A.5.3

Table 1
Characteristics and Qualities of Soils shown on Figure 3
(from the Soil Survey Data Store)

Map No.	Slope	Principal Soil Series	Classification	USDA Texture	Capa-bility Sub-Class	Winter Wheat Yield Bu/A	Dominant Range-Site
32	undu-lating	Ralph	Aridic Argiboroll, fine-silty, mixed	loam	IIIc	20	Silty
36	gently undu-lating	Caputa	Aridic Argiustoll, fine, mixed, mesic	clay loam	IIIc	24	Clayey
39	gently undu-lating	Satanta	Aridic Argiustoll, fine-loamy, mixed	loam	IIIc	22	Silty
44	rolling	Pierre	Ustertic Camborthids, very fine, montmorillonitic, mesic	clay	IIIs	18	Clayey
50	steep	Samsil	Ustic Torriorthent, clayey montmorillonitic	clay	VIs	not adapted	Shallow

	Estimated Engineering Properties*					Degree of Limitation			
Map No.	Liquid Limit	Plasti-city Index	Permea-bility in/hr.	Avail. water capac. in/in.	Shrink Swell Poten-tial	Septic Tank Filter Field	Sewage Lagoons	Corro-sivity uncoated steel	Corro-sivity concrete
32	15-38	5-19	1.2-2.0	.18-.20	low	severe	mod.	high	mod.
36	25-40	11-35	.6-1.2	.19-.22	mod.	severe	mod.	high	mod.
39	22-36	2-15	.6-2.0	.16-.22	low	slight	mod.	mod.	mod.
44	50-82	30-50	<0.06	.08-.12	high	severe	severe	high	high
50	50-100	25-65	.06-.2	.08-.12	high	severe	severe	high	high

*Explanation of the column headings for engineering properties can be found in "Guide for Interpreting Engineering Uses of Soils," USDA Soil Conservation Service, issued Nov. 1971. Washington, D. C. USGPO Stock, No. 0107-0332.

derived Argiustolls) has a pattern indicating some cropping and thus is usually distinguishable from Number 44 - the Pierre association (clayey, shale-derived Camborthids) which is usually in grass. There are two terrace soils shown - number 36 - the Caputa association (clay loam, alluvium-derived Argiustolls) and number 39 - the Satanta association (loamy, alluvium-derived Argiustolls). These two soils, numbers 36 and 39, apparently cannot be distinguished from each other on ERTS-1 MSS images. Both soils also are difficult to distinguish from number 32 except that they usually are intensely cropped while number 32 is about half cropped and half in rangeland. Band 7 gives a better definition of the steeply sloping soil association (50) than does band 5. This is thought to be due to the fact that since a smaller mass of vegetation is produced in this area of dominantly shallow soils, these areas would have a lower reflectance on band 7. Thus the tone on band 7 of these steeply sloping soils would be lighter than that of the adjacent soil associations.

Figure 4 is from southwest South Dakota and on it two ERTS-1 MSS bands are compared with the soil association map of a portion of the Tertiary high plains area. The main soil associations here include the Nebraska sandhills - 164, Valentine association (Ustipsamments, in grass); 59, Minatare association (Natrargids, in grass); 30, Keith association (loess-derived Argiustolls in winter wheat or fallow); 42, Oglala association (loamy, sandstone-derived Haplustolls, mainly in grass); and 26 Kadoka association (silt-stone-derived Argiustolls, mainly in grass). Both bands 5 and 7 show all of these soil associations except perhaps the separation of soil numbers 26 and 42 is somewhat vague. The latter however, is characterized by a lacy white pattern shown especially well on band 5. This pattern is due to the evergreen trees of the Pine Ridge escarpment. The trees have a low reflectance on band 5 compared to the adjacent grasslands. The reflectance differential of the trees and grass is considerably less on the 7 band. The 7 band is useful, however, to show the stockponds and lakes especially prevalent in the sandhills. Also the tonal differences seen in the sandhills soil association are caused by differences in vegetative cover of the rangesites present. Finally, the crops growing on soil association 30, and the others as well, can be catalogued by using the principals described in figure 8.

Figure 5 is from the glacial prairie in northeast South Dakota. The soil associations apparent on this ERTS scene are: 193 - Kranzburg association (loess-derived Haploborolls characterized by regularly shaped fields having no lakes or poorly drained areas); 199 - Forman association (glacial till-derived Argiborolls and Argiaquolls in a hummocky landscape having marshes and lakes); 201 - Forman-Buse association (glacial till derived Argiborolls and Haploborolls in a choppy end moraine landscape); 205 Renshaw association (glacial outwash-derived Haploborolls on irregular relief); 200 - Forman soils on a sloping rather than undulating topography; 212 - Peever association (clay loam glacial till-derived Argiborolls on a nearly level topography); and 219 - Lamoure association (Haplaquolls derived from alluvium). As was discussed earlier for figure 2 the steeply sloping soils in this area stand out as a dark strip on band 7 while the area in trees can be distinguished on band 5. Also band 7 gives superior definition to all water which aids in differentiating soil associations in glacial landscapes since the presence of lakes usually means there are poorly drained soils in the landscape.

In figure 6 the appearance of eroded black and light colored soils and sediments is shown on the four MSS bands of ERTS 1. The dark colored soils are derived from shale high in manganese which outcrops adjacent to the Missouri River reservoir. These dark-colored soils are largely barren of vegetation and can be distinguished on negative prints of bands 6 and 7 as a light colored fringe. These soils have a low reflectance on these bands compared to the adjacent areas in grass. On bands 4 and 5 they have the same reflectance as adjacent areas and hence are not apparent.

Light colored sediments, such as those found in the badlands of South Dakota which are derived from the White River formation, have high reflectances compared to adjacent grass areas. They show as very dark gray or black tones which reflect somewhat differently on all 4 bands from the grass areas. The reflectance differential of white sediments and grass is greater on the 4 and 5 bands, however, than on the 6 and 7 bands.

Monitoring of erosion of soils and sediments by ERTS-1 adds a new dimension to the study of soils on small scale soil association maps. Bare soil areas on slopes contribute sediment to lower lying areas which is a serious pollution problem. The situation causes more concern if a reservoir receives this sediment since this affects the useful life of the reservoir.

Shown in figure 7 is a portion of band 7 of an MSS image of scale 1:1,000,000 along with enlargements of this scene up to a scale of 1:60,000. The image and the enlargements were made from a black diazo transparency which produces a sharp enlargement. One use for enlargements is for crop identification since on them field boundaries can be located and ground truth obtained.

Figure 8 illustrates how the crop use being made of soil associations can be determined by comparing the reflectances of crops on the 4 MSS bands. Enlargements of 1:100,000 appear to work well for this purpose. The land sections are marked out on the enlargements of the bands and comparisons made of the reflectances of the various crops or land uses on the MSS bands. For example on the negative prints shown fallow fields have low reflectance on the 7 band and thus appear in light tones. Native grass has a medium gray tone and wheat and milo have dark tones. Although milo and wheat cannot be separated on the 6 or 7 bands, they can be separated on the 4 or 5 band where milo has a light tone and wheat a dark tone. These examples show that in this area enlargement prints coupled with ground truth data can give very satisfactory preliminary figures on the crop use being made of soil associations. For a report on crop identification involving the computer see the article by Horton and Heilman (1973) and also the paper by Baumgardner et al.(1973).

Figure 9 shows how four lakes in a glacial landscape appear on the four ERTS MSS bands. Water has a low reflectance on the 7 and 6 bands and all water on these scenes will be reflected. On the other hand, marsh vegetation and water have about the same reflectance on bands 4 and 5. Thus it is seen that two of these lakes were marshes when this ERTS scene was recorded. Thus by using the MSS bands marsh and open water can be separated.

Certain glacial soil associations are characterized by lakes, marshes and other poorly drained areas, while others have mature landscapes with well developed surface drains and no poorly drained areas. Haplaquolls occur in the former landscape while they are largely absent in the latter except along the stream courses. Thus knowledge of the hydrology furnished by ERTS 1 images is an aid in identifying soil associations.

A question that suggests itself when viewing ERTS images is, "How accurate are they?" Colvocoresses and McEwen (1973) fitted early MSS images to ground control and found root mean square (rms) distortions of up to 1000 meters, always larger than the 300 meters required by the U. S. National Map Accuracy Standards. Later, however, the images improved and their best results for a frame had an rms of 192 meters. Apparently changes in mirror speed and space craft attitude can be made to further improve the MSS geometric quality.

In summary, the ERTS 1 imagery is a useful tool for the soil surveyor in the preparation of soil association maps. One image covers so large a scene that regional relationships become apparent. This aids in assessing the effect of soil forming factors as well as providing a means of checking the patterns of soil associations over most or all of their area of extent. Each image comes in 4 spectral bands taken every 18 days. Each band gives specific data on relief, hydrology, and vegetation all of which bear on soil association patterns. The bands can be prepared in color composites or photographic or diazo prints, thus allowing a wide choice of images for study and publication.

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Simonson, R. W. 1971. Soil Association Maps and Proposed Nomenclature. Soil Sci. Soc. Amer. Proc. 35: pp. 959-963.

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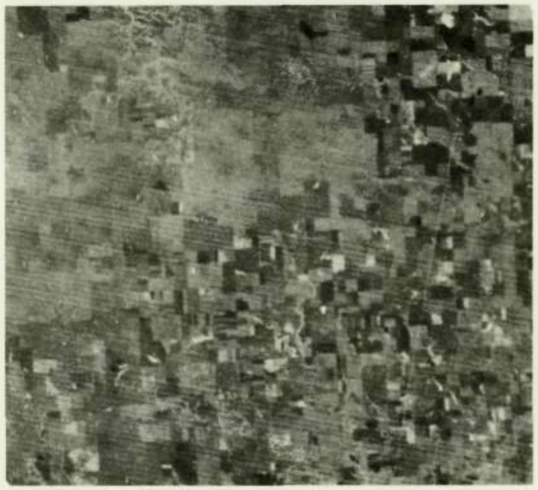
Figure 1 Appearance of soil associations over a climatic range on MSS-5 and 7 of ERTS 1 Negative prints Scale 1:500,000

6 Sept 72 17063	6 Sept 72 17063	14 Aug 72 16382

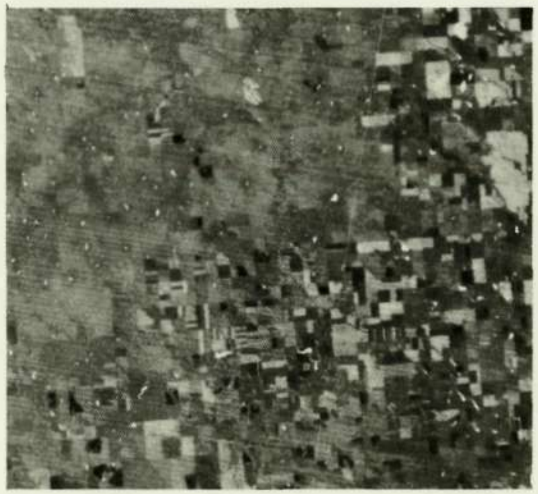
MSS-5



MSS-5

MSS-5

MSS-7



MSS-7

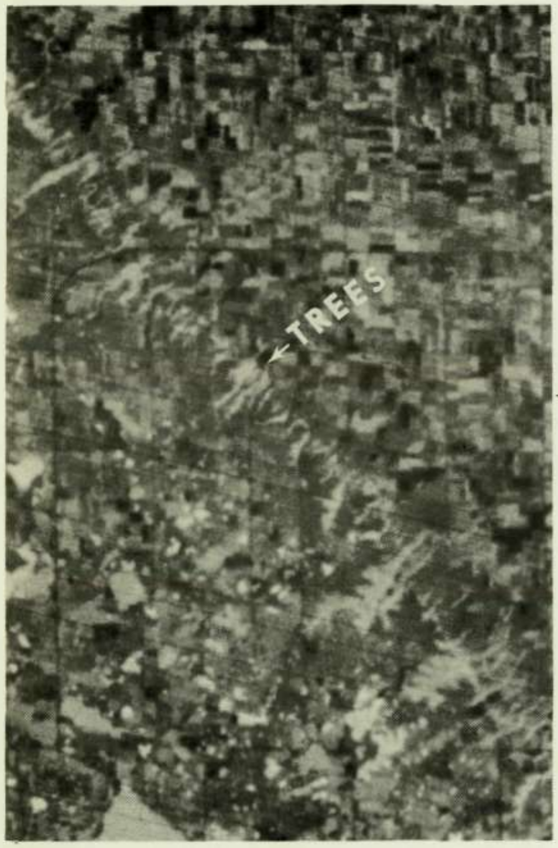
MSS-7

Western South Dakota-355 mm. Ann. Precipitation; 7.2°C Ann. Temperature; mostly rangeland, a few fields with wheat fallow; strip-cropping

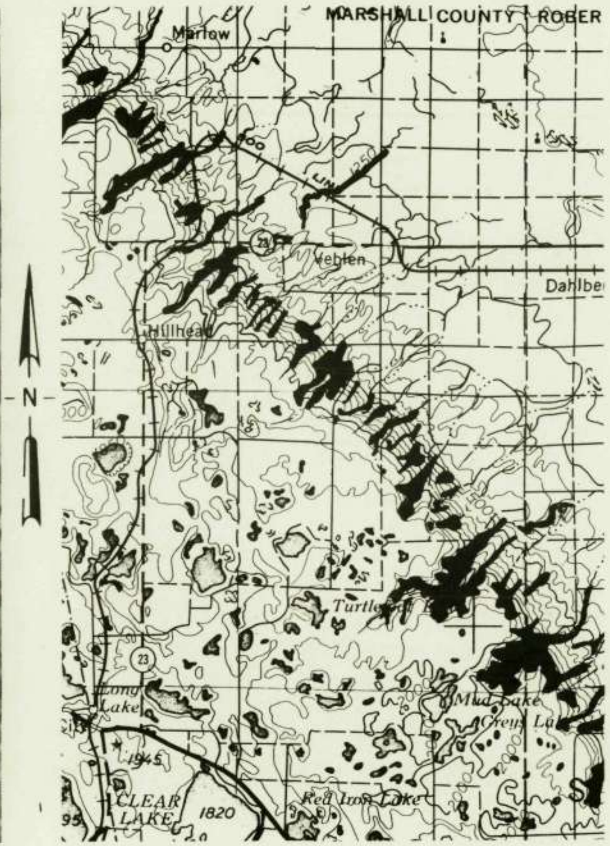
Central South Dakota-432 mm. Ann. Precipitation; 7.2°C Ann. Temperature; about half rangeland half cultivated; large fields; winter wheat fallow

Northwest Iowa-737 mm. Ann. Precipitation; 8.8°C Ann. Temperature; intensively cultivated; small fields; corn, soybeans, hay, pasture

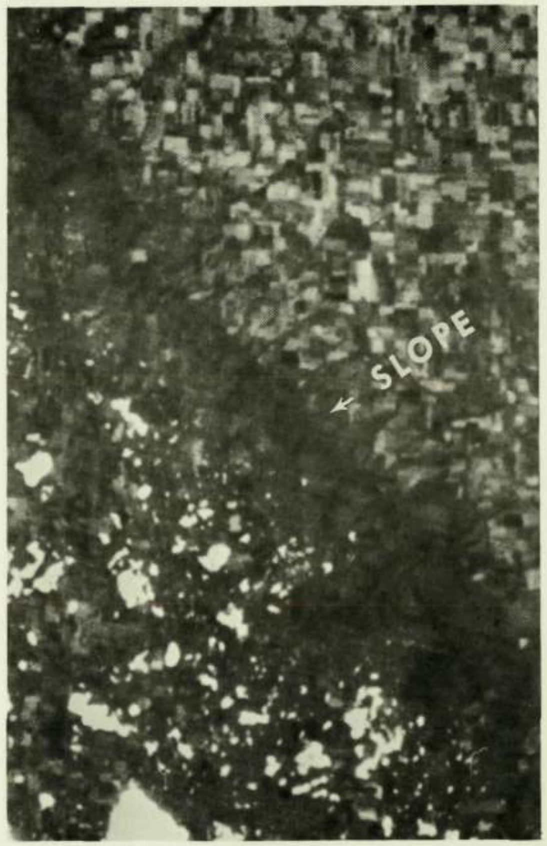
Figure 2 Appearance of Steeply Sloping Area in Northeastern South Dakota
Bands 5 and 7 of ERTS 1 (Negative Prints)



MSS-5 29 July 72 16484
Scale 1:250,000



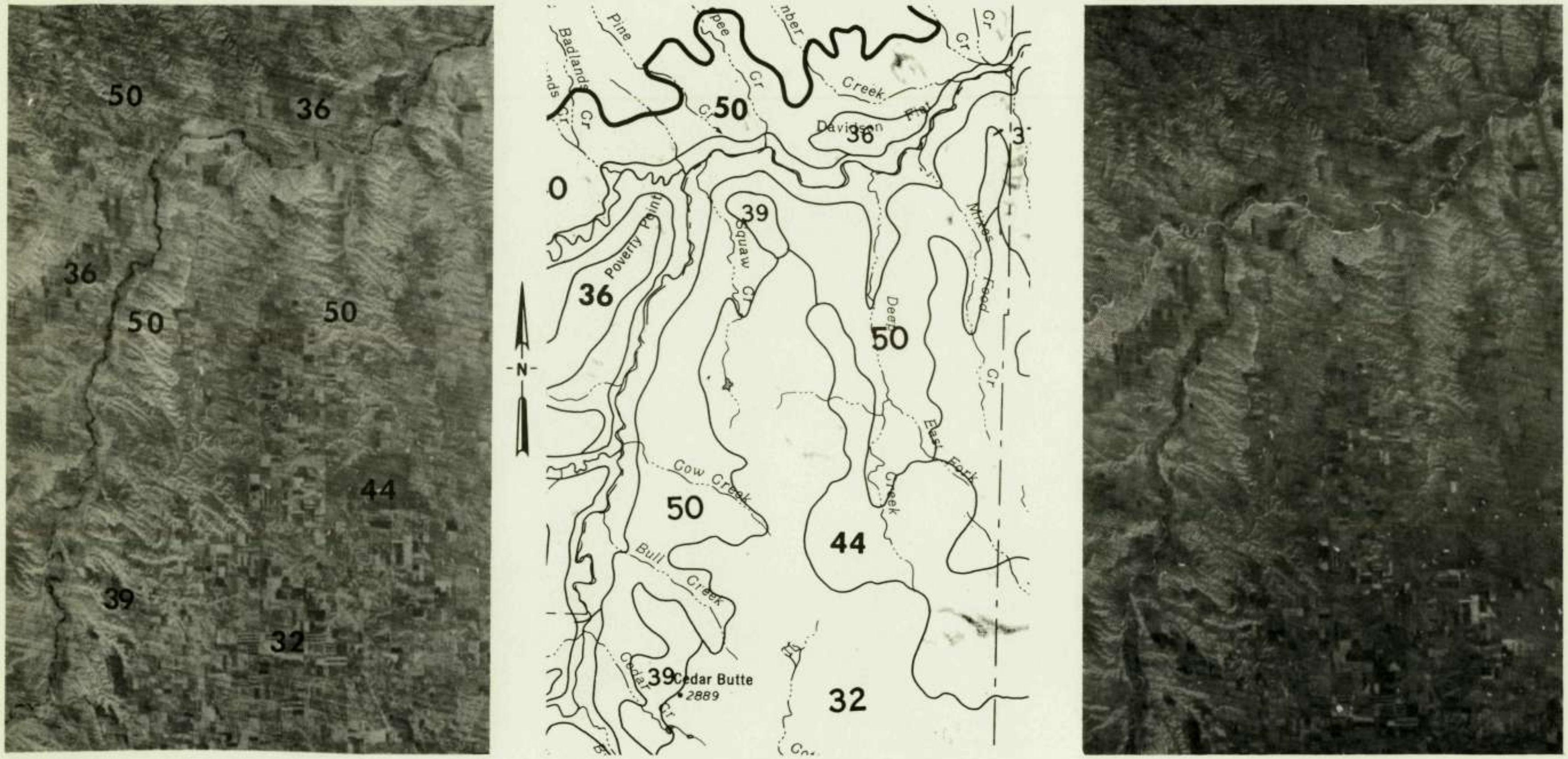
USGS Topographic Map
Scale 1:250,000



MSS-7 29 July 72 16484
Scale 1:250,000

Two kinds of vegetation (grass and deciduous trees) are present on the steeply sloping area passing diagonally across this scene. On band 5 the reflectance of the trees is less than that of the grass or the adjacent crop areas and so they appear lighter on the print. On band 7 both trees and grass on this steep slope have high reflectance compared to the adjacent land and lakes and so the slope stands out as a dark, wide band on the print.

Figure 3 Comparison of Soil Association Map with MSS-5 and 7 of ERTS 1
Scale 1:500,000 Negative Prints Western South Dakota
12 Oct 72 17064 Argiustolls Torriorthents Camborthids



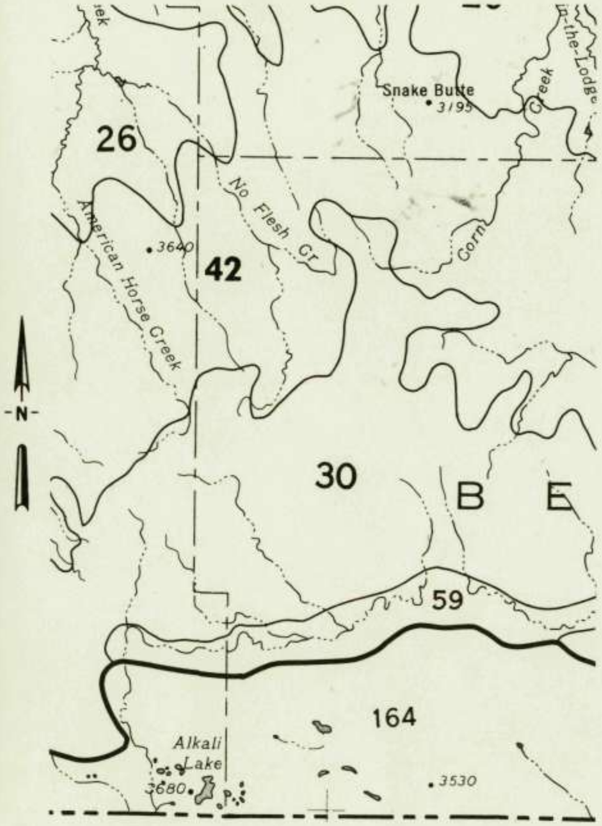
MSS-5

Soil Association Map
Scale 1:500,000
AES Info Series No. 3
SDAES, SDSU Brookings, SD

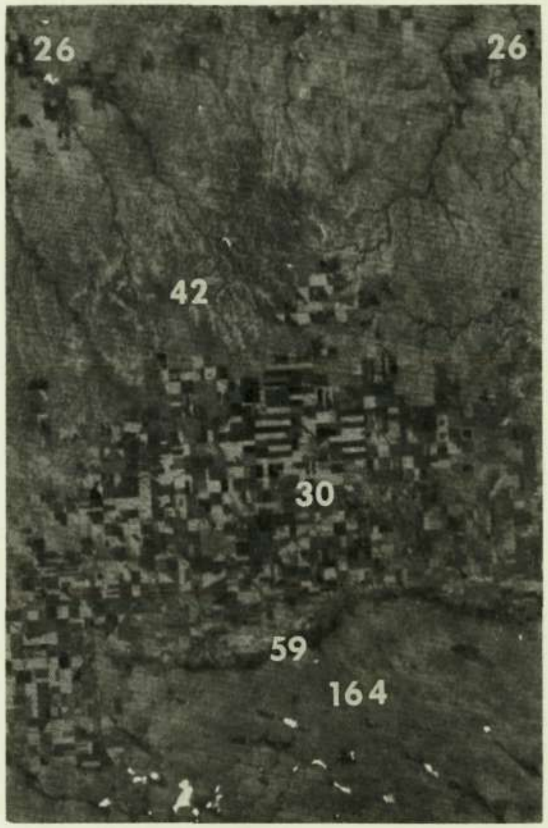
MSS-7

Figure 4 Comparison of Soil Association Map with MSS-5 and 7 of ERTS 1
Scale 1:500,000 Negative Prints Southwest South Dakota
19 Aug 72 17065 Argiustolls Haplustolls

MSS-5

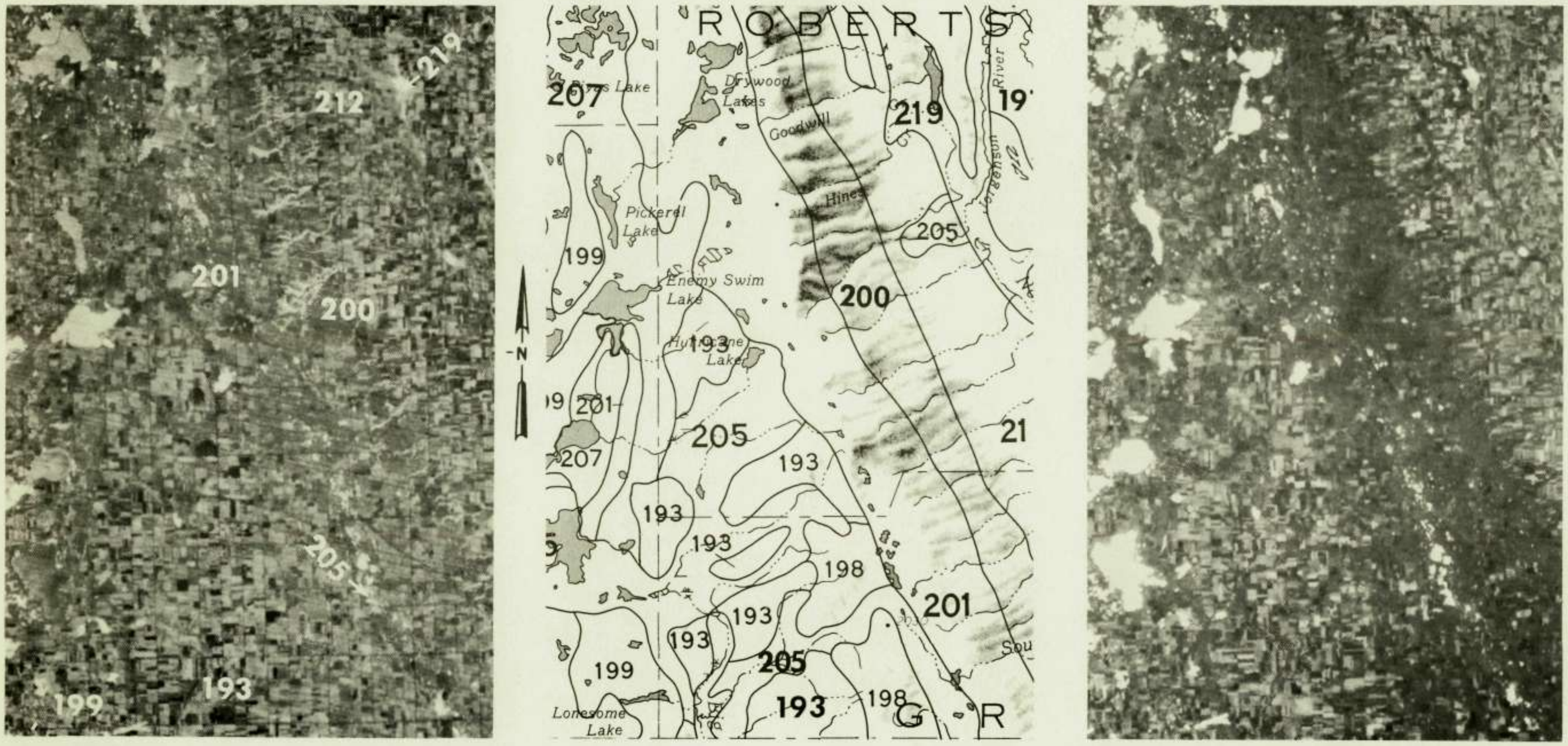


Soil Association Map
Scale 1:500,000
AES Info Series No. 3
SDAES, SDSU Brookings, SD



MSS-7

Figure 5 Comparison of Soil Association Map with MSS-5 and 7 of ERTS 1
Scale 1:500,000 Negative Prints Northeast South Dakota
29 July 72 16484 Argiborolls Haploborolls



MSS-5

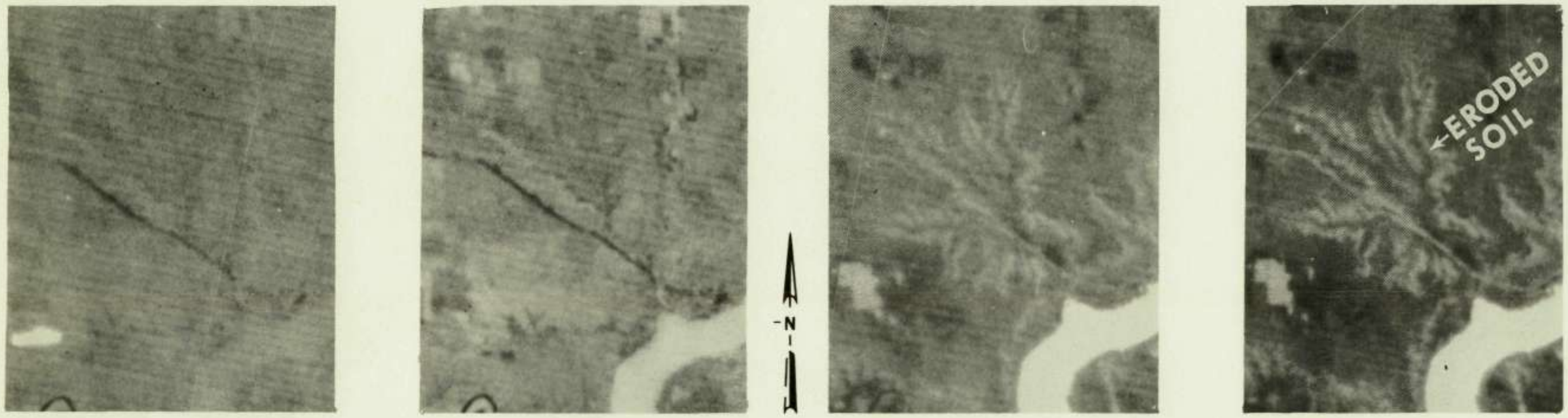
Soil Association Map
Scale 1:500,000
AES Info Series No. 3
SDAES, SDSU Brookings, SD

MSS-7

Figure 6 Appearance of erosion of black and light-colored soils and sediments on ERTS 1 imagery Negative prints Scale 1:250,000

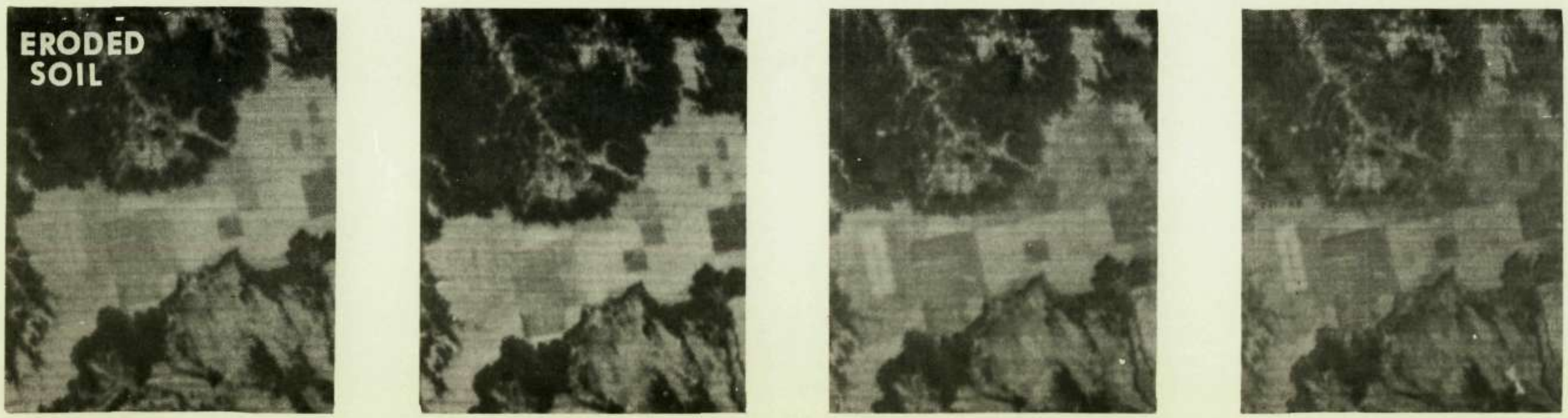
(Black eroded soils have low reflectance on IR bands 6 and 7 compared to adjacent vegetated areas and stand out as a white fringe. Light colored eroded soils have higher reflectances and thus appear darker on all bands than adjacent vegetated areas).

Erosion of black, shale-derived soils above Missouri River Reservoir ERTS 1 17 Aug 72 16551



MSS-4 MSS-5 MSS-6 MSS-7

Erosion of light-colored soils in Badlands ERTS 1 19 Aug 72 17065

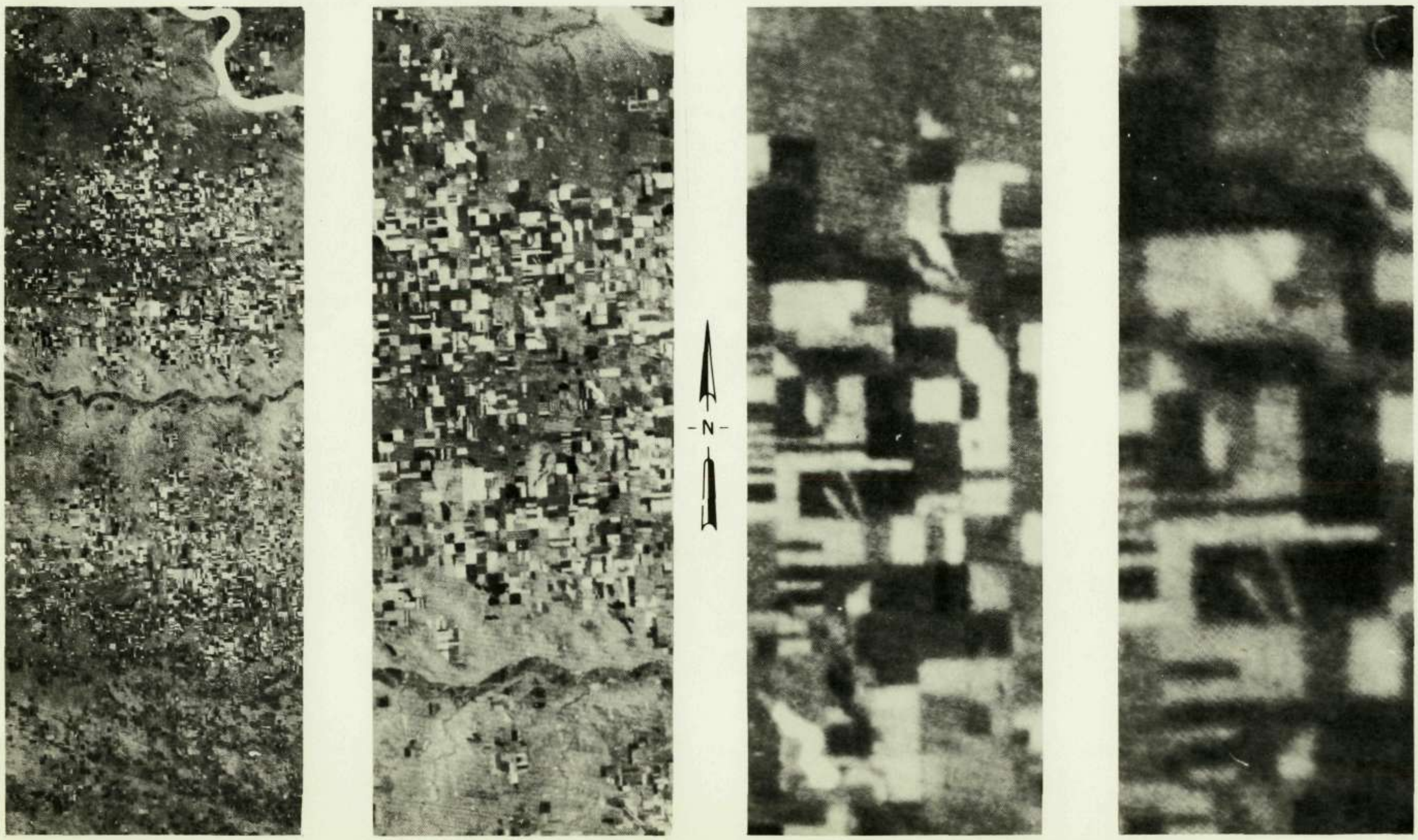


MSS-4 MSS-5 MSS-6 MSS-7

Figure 7 Enlargements of Band 7 of an ERTS 1 Image

Utilization of soils can be determined by comparing reflectances of the MSS bands. These enlargements show that individual fields can be identified for purposes of determining land use.

Negative Prints made from Band 7 of a black diazo transparency 17 Aug 72 16551-7

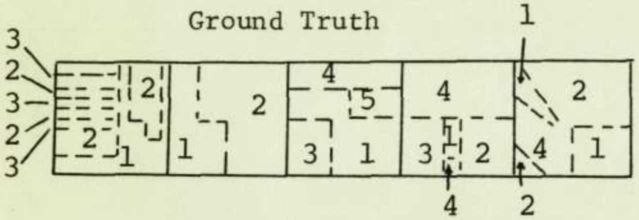


Scale 1:1,000,000 Scale 1:500,000 Scale 1:100,000 Scale 1:60,000

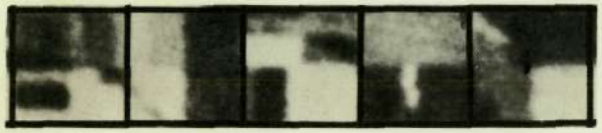
Figure 8

Identification of crops grown on Soil Association Opal-Promise(Vertic Haplustolls, very fine, montmorillonitic, mesic)on 4 bands of ERTS 1.Negative prints made from black diazo transparencies. Sections 1 through 5 of T106N, R77W, Lyman County, S.D. 17 Aug 72 16551 Scale 1:100,000

Ground Truth



1. Fallow
2. Wheat
3. Milo
4. Native grass
5. Tame grass

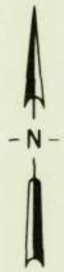


MSS-7

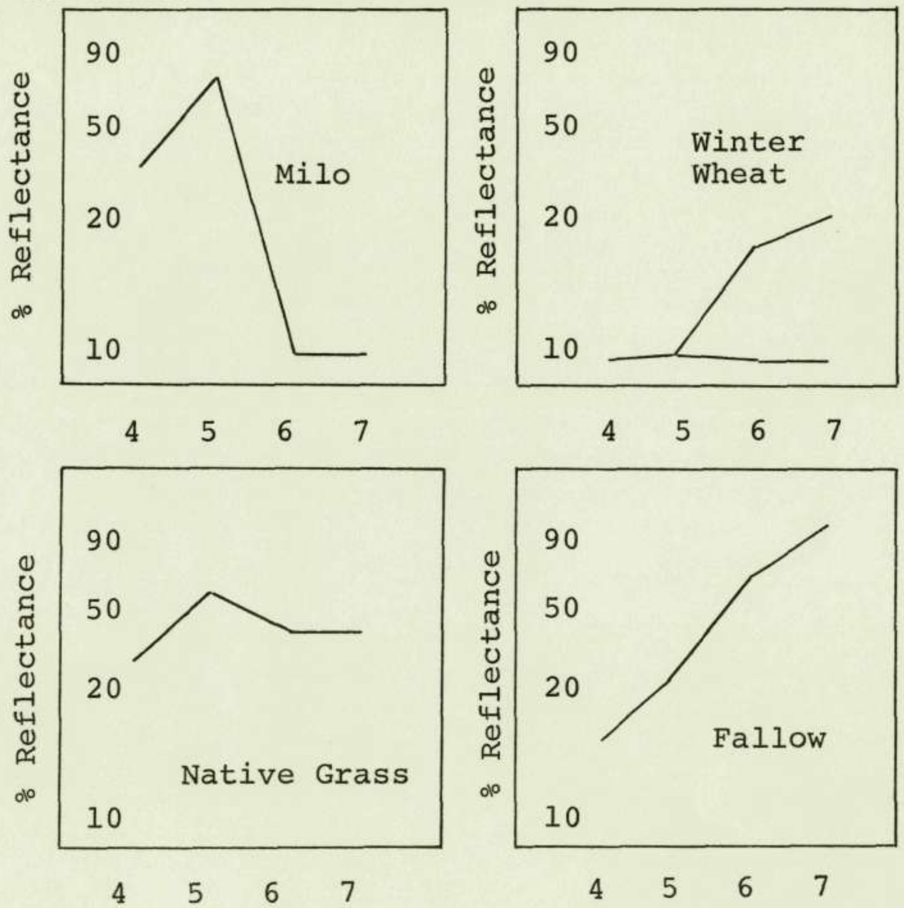
MSS-6

MSS-5

MSS-4



Reflectances on MSS bands 4,5,6 and 7 for crops measured on Macbeth Reflection Densitometer Model RD 219



Wheat and milo can be separated on bands 4 and 5, but not on bands 6 or 7. Fallow and native grass can be separated on bands 6 and 7, but not clearly on bands 4 or 5. Thus, utilizing band 6 or 7, fallow and native grass can be distinguished from each other and from wheat and milo. Then, using band 4 or 5, milo can be distinguished from wheat. Note that on these negative prints the low reflectances have a light tone and high reflectances a dark tone.

Figure 9 Appearance of lakes and marshes on 4 MSS bands of ERTS 1
Eastern South Dakota glacial soil areas
21 Sept 72 16491 Scale 1:250,000 Negative Prints