Paper A 12

ERTS-1 MSS IMAGERY: ITS USE IN DELINEATING SOIL ASSOCIATIONS AND AS A BASE MAP FOR PUBLISHING SOILS INFORMATION.[1]

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ABSTRACT

ERTS 1 imagery is a useful tool in the identification and refinement of Soil Association areas and an excellent base map upon which soil association information can be published. Prints of bands 5 and 7 were found to be most useful to help delineate major soil and vegetation areas. For example band 7 was found to give superior definition to steeply sloping soils while band 5 gave the best contrast between trees and grass. After delineating major soil areas, over 4800 land sale prices covering a period of 1967-72 were located in the soil areas and averaged. A legend explaining land use, dominant slope and soil parent materials of each delineated area was developed. The soil associations then were described as Soil Association Value Areas and published on a 1:1,000,000 scale ERTS mosaic of South Dakota constructed using negative prints of band 7. The resulting map describes the kind of agriculture and soils and allows readers to see how soils actually are being used on a near orthographic current map. Furthermore, it gives information about what buyers think the soils are worth. The map is intended for use by state and county revenue officers to equalize land values in South Dakota, by individual buyers and sellers of land and lending institutions as a reference source, as a reference map by those planning road routes and cable lines and pipelines, by conservationists in helping to keep current conservation needs inventories, by agronomists needing current information on distribution and patterns of crop growth and by crop yield forecasters to guide sampling strategy.

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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 evaluating land, 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 are soil landscapes that occur in repeating patterns. They may contain like or unlike soils but the association itself is homogeneous and different from other soil associations when viewed on the imagery.

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.

Five factors control the formation and distribution of soils and soil associations. These are: climate, organisms (dominantly native vegetation), soil parent material, topography and time. With the exception of time these factors define the environment of soil formation. Time gives the total potential for change, and is not considered in this study as a separate factor resulting in recognizable boundaries. Climate and native vegetation are closely related and usually are considered together since both are dynamic factors acting upon soil parent materials on different topographic sites.

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 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.

The objective of this study was the recognition of Soil Association boundaries on ERTS-1 images and mosaics and the publication of a soil association map on an ERTS-1 mosaic of South Dakota.

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 two 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 under magnification; 2) negative prints of scale 1:500,000, 1:250,000, 1:100,000 and 1:60,000.

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.

CHARACTER OF SOIL BOUNDARIES DUE TO CLIMATE AND VEGETATION AND THEIR RECOGNITION

Soil profiles cannot be seen on either air or satellite imagery and for a large part of the growing season each year even the surface soil of South Dakota is covered with vegetation. Thus, recognition of soil association boundaries must be inferred in part from the patterns made by the present vegetation since this is the principal way that climate and native vegetation are expressed.

Soil Association boundaries separate kinds of agriculture. For example, corn and soybeans are grown in South Dakota in the eastern and southeastern part where the soils have developed under a warm-moist climate and tall grass vegetation. Moving northwest, spring wheat takes over as the main crop. Spring wheat is at its peak of green growth in June at which time corn is just beginning to mantle the soil. Thus, band 7 of May ERTS passes will show high reflectance where spring wheat is the dominant crop. On August imagery the corn and soybean-growing soil associations will reflect strongly while the soil associations used for spring wheat will have low reflectance. Thus, both the temporal and multispectral characteristics of ERTS imagery are utilized in recognizing boundaries of soil associations. Other characteristics used include field size (larger in wheat area) and percentage of the soils in pasture or range grass (larger in wheat area).

Some role in soil formation is played by both precipitation and temperature. Precipitation affects the amount of water that enters the soil and hence the chemical and physical weathering processes, eluviation and ion movement. Moisture relationships also affect the amount of residues that are returned to the soil and the speed of their decomposition.

Temperature controls the heat available for the physical, chemical and biological processes of soil formation. Weathering generally increases with an increase in temperature if moisture is not limiting. Also, higher temperatures generally increase the rate of organic matter decay.

The general characteristics of soils can be related to climate. Although there are many interrelationships, the most significant ones generally relate to a single soil property such as organic matter content and a single climatic component like precipitation. The climate in South Dakota is subhumid in the eastern part and semiarid in the central and western parts. Tall grass prairie was the principal vegetation in the subhumid east while mid and short grasses were the native vegetation types in the semiarid central and western parts.

The principal biotic factor in soil formation is vegetation since it is the major source of organic matter. The effect of vegetation on soil properties differs with the kind of vegetation. Grasses contribute large amounts of organic matter that darken the upper layers of soil. The intensity of the development of these upper horizons correlates well with the climate resulting in darker and thicker dark colored horizons in eastern South Dakota and gradually thinning and becoming lighter colored in moving to the northwest corner. Since climate is a continuum the soil thickness and darkness also are a continuum. As long as soil parent material and topography are constant factors the soil boundaries related to climate and native vegetation are gradual. Thus, the problem of delineating soil boundaries which are due to climate has been difficult by conventional means since no one aerial photograph or county mosaic covered sufficient area to see evidence of soil differences that could be attributed to climate and vegetation.

ERTS scenes cover larger areas, however, and this synoptic view provides an opportunity to observe soil associations and their use over an area of climatic change. As mentioned, however, climatic change is gradual and as long as soil parent material and topography remain constant, the soil association boundaries that result from climatic change are gradual. Fortunately, however, there often is a topographic or soil parent material change which provides a distinct boundary and the climatic continuum can be partitioned in this manner. Figures 1 and 2 illustrate this point. Figure 1 is of western Minnesota along latitude 44°15. The climate gradually is becoming drier from east to west. This is seen in the gradual darkening of the tone of the MSS-7 negative print. This tone darkening is due to an increased percentage of spring grain which is near its peak of green growth on 17 June. The more humid eastern area is planted to corn and soybeans neither one of which has produced much vegetation by this date. Three soil parent material boundaries occur on the scene at roughly right angles to the climatic change. These soil parent material boundaries then serve also to partition the climatic continuum. Figure two is from east-central South Dakota. Here, also, the climate gradually is becoming drier from east to west and this is seen on the MSS-7 negative print as a gradual darkening of the tone of the image due to a change in crops grown from more corn to less corn. This ERTS scene is of 16 May when corn is in the process of being planted and thus the corn land reflects very light gray on the negative print of MSS-7 while the wheat, which is present in larger proportion on the west, has a dark tone. The light tones signifying corn land are present in larger proportion on the east part of the figure. Crossing at nearly right angles to this climatic change is a soil parent material change which then also serves as a boundary for a climate change.

RECOGNITION OF SOIL ASSOCIATION BOUNDARIES CAUSED BY SOIL PARENT MATERIALS

Soil parent materials may be classified into one of three groups: residual, transported and organic. Since organic materials are not present in soil associations in South Dakota they are not discussed further here.

Residual soil parent materials include hard igneous and metamorphic rocks, as well as hard and soft sedimentary rocks. The hard rocks weather very slowly to produce thin soils. In South Dakota these occur in the Black Hills and are further distinguished by rugged mountainous relief. These areas of different rocks have sharp boundaries visible on MSS-5 and 7 of ERTS (see figure 3). They have greatest reflectance differences with surrounding areas on band 5 than the other bands. Softer sedimentary rocks include sandstones, limestones and shales. These along with alluvium and loess characterize the west half of South Dakota.

Soil Association boundaries caused by a change in the soft sedimentary rocks are sharp in South Dakota, and visible on ERTS images in any season and on bands 5, 6, and 7 or on color composites. Several kinds of soft sedimentary rock soil parent material are shown of figures 4 and 5. The Sand Hills consist of unconsolidated deep coarse sands on undulating or hummocky relief used for range grasses. The Pine Ridge is from a partially cemented calcareous sandstone and the soils here are generally shallow sandy loams on steep, north-facing slopes. This environment is suited for range grasses and Ponderosa Pine. The pine grows generally on the steepest valley sides and its reflectance is much lower on band 5 than is the grass. Thus on this band there is a unique veining pattern following the location of the Ponderosa Pine.

The siltstone in this area is high in calcium carbonate and light tan to white in color. The soils that develop from them are thin, especially on the slope breaks and knobs and the whitish parent material gives a high reflectance on band 5 of ERTS. The siltstone area erodes to barren badlands where a slope differential or wall occurs but otherwise is used mainly for growing range grasses and occasionally a field of winter wheat. The appearance of the siltstone area on ERTS imagery then is one of uneven tone caused by the association of moderately deep and shallow soils and the boundaries separating the area from the adjacent soil asociations is sharp.

The shale in this area is a rather dense, very fine-textured marine deposit and the relief on which it occurs is rolling. The fine textures and strong relief result in high runoff so the production of grass (which is the main use) is low. Thus the IR reflectance generally of these areas is low. The high runoff from these clay materials is carried from the uplands mainly by a fine network of closely spaced streams. This stream network and the low IR reflectance are two features identifying the shale soil parent materials. The boundary separating shale from associated soil parent materials in this area usually is sharp and is visible on the ERTS images, especially on band 7. Figure 5 shows the delineation of soil association boundaries between a dense shale and a sandstone.

Transported soil parent materials usually are named to show the principal agency responsible for transportation and deposition. A common feature of transported soil parent materials is that they occur in an unconsolidated state, thus they give rise to deeper soils generally than do residual materials.

The transported soil parent materials can be subdivided into deposits from running water, glacial deposits, and wind-laid sediments. Running water deposits include alluvium and terrace materials. For major rivers, boundaries of both deposits can be distinguished on ERTS images. Alluvial deposits are identified by stream proximity, linear shape and usually by having a network of drains. In addition, the valley floor and bluff usually have a sharp boundary caused by reflective differences of the valley floor vegetation and the sparser vegetation of the steep valley sides. Figure 6 shows the delineation of the Big Sioux River bottomland and a terrace near Brookings.

Terrace soil parent materials also occur near streams, but back from the alluvial plain. They also usually have linear shapes but lack a network of drains since they are above the level of flooding. Since they occur on flat topography and the materials are friable, the soils usually are among the most productive for their area of occurrence and are under cultivation. Thus a field pattern of cropland with few, if any, areas of grass or trees further characterizes terraces in South Dakota. Since these soils are the most productive in their area, the total biomass produced is larger than surrounding areas and terraces have higher reflectance on band 7 than adjacent areas.

Glacial soil parent materials in South Dakota include till and outwash. Till is generally medium textured and is deposited in undulating ground moraines and steep end moraines. Glacial outwash, which is coarse textured, is carried by water beyond the ice front onto a plain. Glacial till soil parent materials on undulating or nearly level slopes and outwash plains generally are under cultivation and so have a pattern of field boundaries. Steeply sloping or hilly glacial soil parent materials generally are in grass or trees, thus land use is useful in the separation of these two kinds of glacial till soil parent material. Figure 7 illustrates the distinct boundaries on MSS-7 imagery that separate a dead ice moraine, an end moraine, and ground moraine in north central South Dakota. Each of these is a Soil Association area.

In general, boundaries separating glacial soil parent materials can be distinguished from residual soil parent materials on ERTS. The residual soil parent materials are on an erosional landscape consisting of broad ridge tops, valley sides and well defined stream courses. The glacial landscape is one where the land forms have been constructed by glaciers. It consists of broad plains interrupted by hilly ridges. The stream drainage pattern is less well defined and often the glacial plain is dotted with morainic depressions, marshes and lakes. See figure 8.

Boundaries separating mature glacial plains can further be distinguished from immature glacial plains in that the former has a well developed network of streams and the latter is characterized by poorly drained areas and no stream surface drainage network. See figure 7. Band 7 is superior for boundary detection in glacial areas since all water bodies are clearly shown.

The wind-deposited soil parent materials in South Dakota include loess which is silt size, and eolian sand. Loess deposits are superior soil parent materials since they are friable and permeable. Thus they are cultivated for the most part even in semiarid climates. Figure 9 is an ERTS image from southeast South Dakota. Here a thick loess occurs on a rolling upland which dictates use of a high percentage of close-growing crops like small grain to help control water erosion. On June imagery these crops are near their peak of green growth and thus reflect strongly on MSS-7. The flat areas are used for corn and soybeans primarily and these crops have not grown sufficiently by mid June to give much reflectance on MSS-7. Therefore, these areas have light tones on the negative prints of figure 9.

Field patterns often indicate loess soil parent materials in western South Dakota. See figure 4. The boundaries separating loess from eolian sand and residual sandstone are sharp as is shown in the figure. Eolian sand soil parent materials also have sharp boundaries with loess and sandstone. The identification keys for eolian sand soil parent materials are that the areas are in grass (because of the severe wind erosion hazard), they lack any surface streams and their general configuration is one of hummocks and ridges interspersed with small flats, dips and depressions. The boundaries delineating eolian sand soil parent material are distinct on ERTS images.

RECOGNITION OF SOIL ASSOCIATION BOUNDARIES CAUSED BY TOPOGRAPHY

Topography affects soil formation mostly by modifying the climate. Precipitation effectiveness is influenced by runoff which is controlled by topography. Likewise the slope aspect and degree of slope affect the amount of solar radiation received which in turn affects soil temperature and evaporation. Thus the climatic environment induced by topography affects the vegetation and the boundaries delineating this climatic effect can be observed on ERTS images. This is shown on figure 10 where the steep slope of the Prairie Coteau appears as a wide, dark area on MSS-7 while it is not apparent on MSS-5. The evidence of steep slopes along valley sides can also be inferred from the close spacing of drains into a river valley as is shown in figure 11. Here the evidence is apparent on both bands 5 and 7.

Differences in soil moisture regimes influenced by topography are significant. In the sandhills the low lying basins receive runoff and have poorly drained soils high in organic matter. Although small basins usually are not individually separated on soil association maps, their presence or absence is a characteristic of the soil association, and hence being able to see their boundaries on ERTS is significant.

Upland and lowland is a broad topographic classification of soil associations. Lowlands include alluvium and terrace soils which usually have well defined boundaries visible on ERTS.

Upland soils on undulating topography generally are described as mature since they reflect the normal expression of the climate of the area. On steep slopes thin profiles generally erodes as fast as new soil develops. These thin soils produce less vegetation than the associated normal soils for two reasons -- they are thinner and less well supplied with nutrients and they receive less effective moisture for plant growth. Thus the MSS-7 is the most useful to distinguish the boundaries of these thin, steeply sloping soils. This is shown on figures 10 and 11.

THE RELATIONSHIPS AMONG THE SOIL FORMING FACTORS

Variation in any of the factors of soil formation can change the soil association. Often the factors interact and the effect is additive or one may nullify another.

In figures 1 and 2 a climatic change is apparent from east to west as corn acreage decreases and spring wheat acreage increases. The climatic boundary is gradual but distinct topographic or soil parent material boundaries occur. Thus a topographic or a soil parent material boundary also serves to divide the climatic continuum. Soil parent material and topography usually change abruptly and these changes produce boundaries visible on ERTS. Because of the reflective contrasts produced on MSS-7 by vegetative differences, the seasonal greening of vegetation coupled with crop calendar information provides a good tool to distinguish Soil Association boundaries. This temporal advantage coupled with the multispectral advantages make ERTS a valuable tool in distinguishing Soil Associations.

USE OF AN ERTS-1 MOSAIC OF SOUTH DAKOTA AS A BASE FOR PUBLISHING A SOIL ASSOCIATION VALUE MAP

Soil Association maps for large areas at scales of 1:1,000,000 and 1:500,000 usually are published as line maps or in color. The cost of publishing these maps on conventional aerial photographs would be excessive. 1/ A mosaic constructed from ERTS costs relatively little, however, since only 20 ERTS scenes are needed to cover the entire state of South Dakota. Moreover, the image approximates an orthographic view resulting in little distortion. Another advantage of ERTS is that a near real-time view of the scene is afforded and so the current use of the soil associations can be observed and studied. The map also can be updated each year with current ERTS imagery.

A Soil Association Value Map of South Dakota on an ERTS-1 mosaic has been published as SDSU-RSI-73-17 and is available from the Remote Sensing Institute, South Dakota State University, Brookings 57006. This map was constructed as follows. After delineating the major Soil Associations with the aid of ERTS imagery, over 4800 land sale prices covering a period of 1967-72 were located in the soil areas and averaged. A legend explaining land use, dominant slope and soil parent materials of each delineated area was developed. The soil associations then were described as Soil Association Value Areas on a 1:1,000,000 scale ERTS mosaic of South Dakota constructed using negative prints of band 7. 2/ Negative prints were used because they are a generation closer to the ERTS imagery than positive prints. MSS-7 was used because of its usefulness in detecting growing vegetation, its good contrast, its ability to delineate water and its ability to penetrate haze. The resulting map describes the kind of agriculture and soils and allows readers to see how soils actually are being used on a current map having very little distortion. Furthermore, it gives information about what buyers think the soils are worth. The map is intended for use by state and county

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1/ It is estimated that it would take about 30,000 conventional aerial photographs to cover South Dakota.

2/ Appreciation is expressed to Jack Smith, Photographic Technician, RSI, SDSU, Brookings, for preparing the ERTS mosaic of South Dakota.

revenue officers to equalize land values in South Dakota, by individual buyers and sellers of land and lending institutions as a reference source, as a reference map by those planning road routes and cable lines and pipelines, by conservationists in helping to keep current conservation needs inventories, by agronomists needing current information on distribution and patterns of crop growth and by crop yield forecasters to guide sampling strategy.

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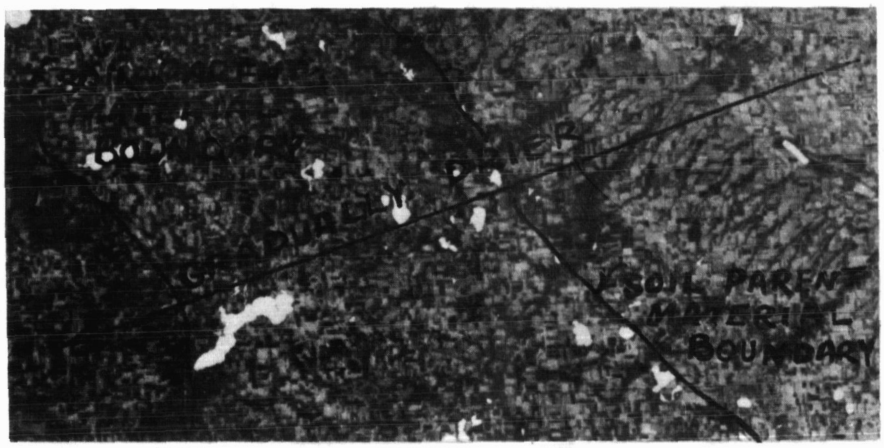
Figure 1

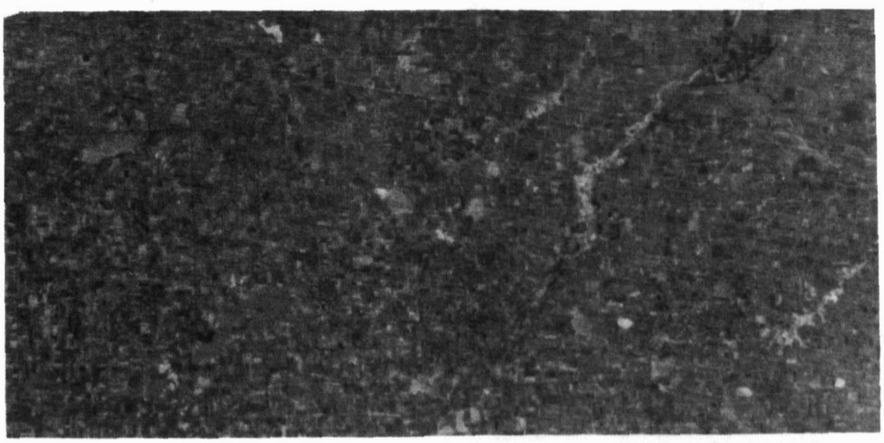
Use of ERTS-1 to detect Soil Association boundaries due to climatic differences

Negative prints, Scale 1:500,000, Western Minnesota 17 June '73

Along 44° latitude precipitation decreases in western Minnesota as the South Dakota state line is approached, and this fact is recognized by farmers who increase the proportion of small grain (a crop requiring less moisture) relative to corn and soybeans. On MSS-7 of this negative print from 17 June imagery, the lighter tones are on the more humid east, where most of the land has been planted to corn or soybeans about a month earlier. These crops have not yet mantled the soil so a large part of the reflectance on MSS-7 is of the soil. Moving west the number of fields in small grain (which is at its peak of green growth on 17 June and thus reflects strongly on MSS-7) increase, gradually increasing the proportion of dark tones on MSS-7. MSS-5 does not show these tonal differences.



MSS-7



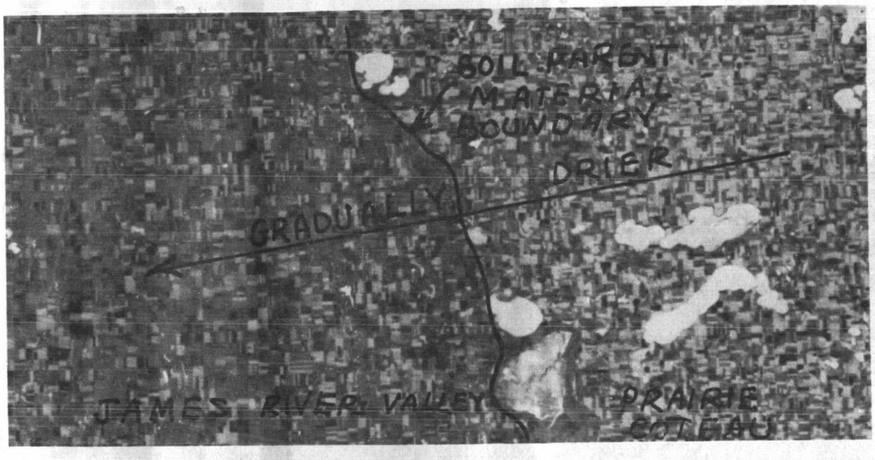
MSS-5

Figure 2

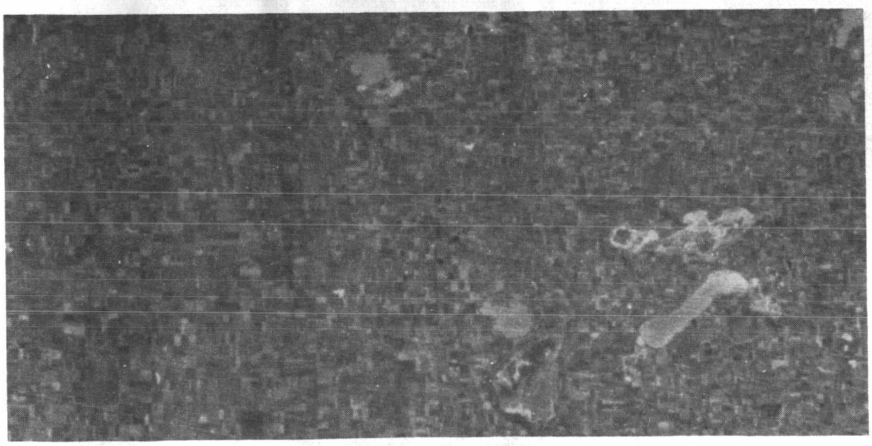
Use of ERTS 1 to detect Soil Association boundaries due to climatic differences

Dry subhumid and moist subhumid climates, glacial soils

In this May 16, 1973 ERTS scene, the moist subhumid Prairie Coteau (Udic soil subgroups) on the east has a higher proportion of corn and soybeans than the dry subhumid James Valley (Typic soil subgroups) which is primarily in spring grain and grass. Since the spring grain and grass are near their peak of green growth on this date, they have higher reflectance on band 7 than the Prairie Coteau which has a smaller mass of vegetation and hence has a comparatively low reflectance. This climatic boundary is apparent on MSS 7 but not MSS 5. Scenes taken in August also will show this but the reflectances on band 7 will be reversed from that shown on the May scene.



MSS-7



MSS-5

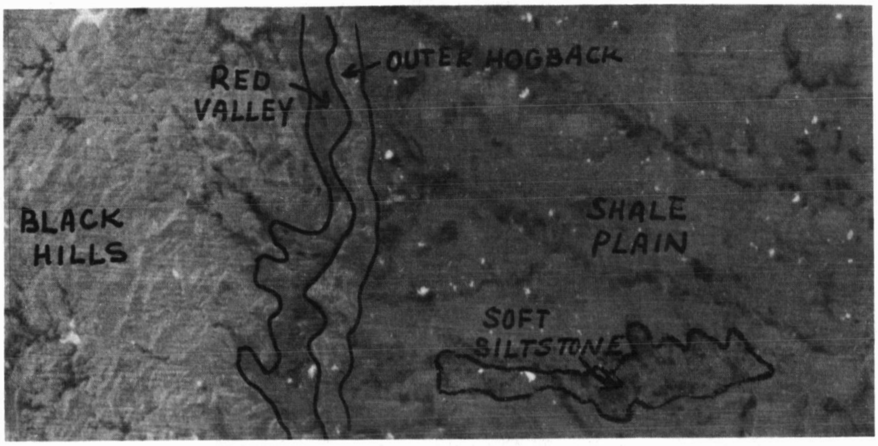
Figure 3

Use of ERTS 1 to detect Soil Association boundaries due to soil parent material differences

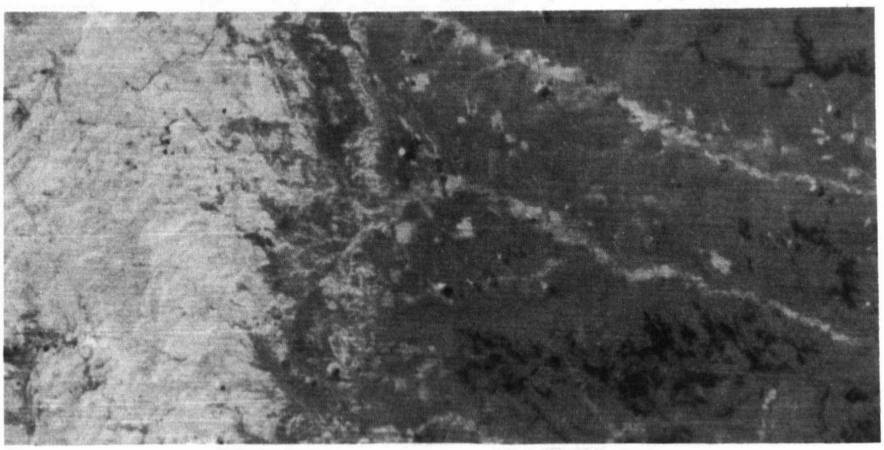
Limestone, Sandstone, Shale, Siltstone

Negative Prints, Scale 1:500,000, Western South Dakota

On this May 16, 1973 scene, the Black Hills area shown is developed from a hard limestone and is mantled with coniferous vegetation; the Red Valley is from a soft shale and is in grass; the Outer Hogback is from a hard sandstone and is partly in grass, partly in trees; the soft shale plain is in grass; and the light-colored soft siltstone area is barren badlands. The boundaries of each of these soil parent materials are apparent on both MSS 5 and 7 of ERTS but the contrast among these materials is more pronounced on MSS 5 than on 7.



MSS-7



MSS-5

Figure 4

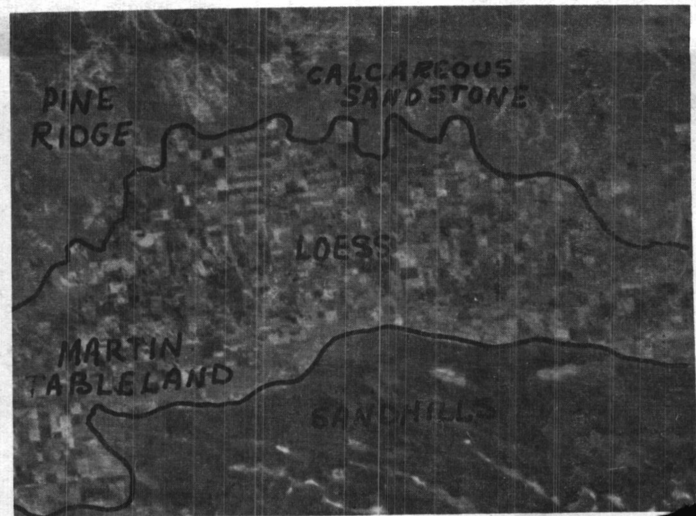
Use of ERTS 1 to detect Soil Association boundaries due to soil parent material differences

Sandhills, Loess, Sandstone (Semiarid climate)

Negative Prints, Scale 1:500,000, Southwestern S. D.

On this May 1973 scene, the boundaries separating sandhills, loess and sandstone are readily apparent on both MSS 5 and 7, however, the gray tones denoting reflective differences are most apparent on MSS 5. Both the Sandhills, and the Pine Ridge are in grass but the latter has a well developed network of streams denoting low soil infiltration rates due to steep topography or slowly permeable soils or both. The nearly white fringe area along the drains is due to the low reflectance of the Pine trees and is seen best in MSS-5. The Sandhills has no drainage network indicating a high infiltration rate as would be expected on a sandy soil. The loess area is characterized by a field pattern of fallow (light gray on MSS 7) winter wheat (dark gray on MSS 7) and milo (also light gray on MSS 7). In the semiarid climate characterizing this area, only the most favorable soils are cropped. Conversely, since the income from wheat and milo is higher than from grass, few favorable soils are not cropped; thus, in this area land use correlates with soil quality.

MSS-7



MSS-5

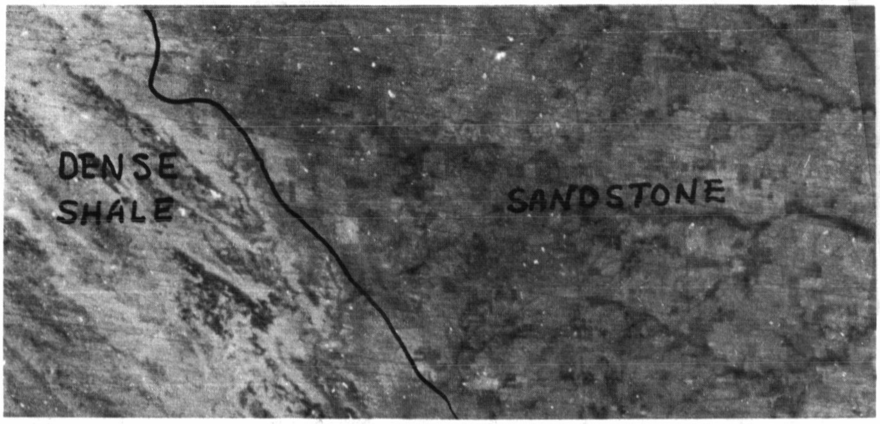
Figure 5

Use of ERTS 1 to detect Soil Association boundaries due to soil parent material differences

Dense Shale and Sandstone, Semiarid Climate

Negative Prints, Scale 1:500,000, Western South Dakota

On this May 15, 1973 scene, the dense shale soil area is nearly barren of vegetation while the sandstone area has a modest cover of cool season grasses and an occasional field. On band 7 the dense shale-derived Winler soil area has very low reflectance appearing nearly white on the print. Tonal differences between these two soil parent materials is not as pronounced on band 5.



MSS-7

MSS-5

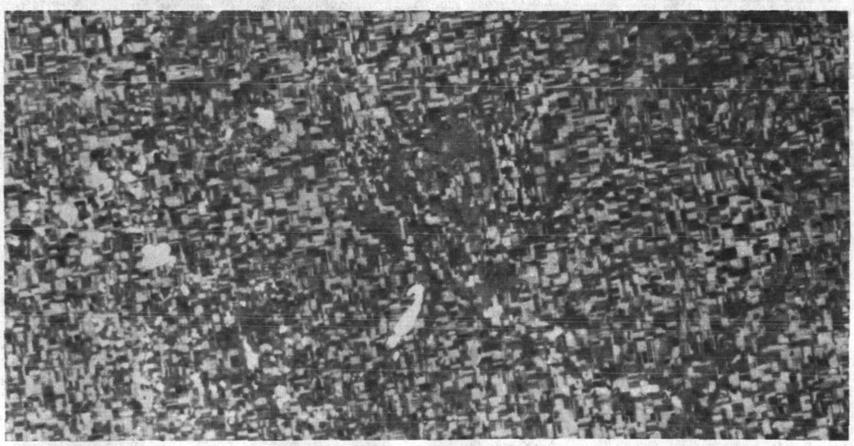
Figure 6

Use of ERTS 1 to detect Soil Association boundaries due to soil parent materials and land form differences

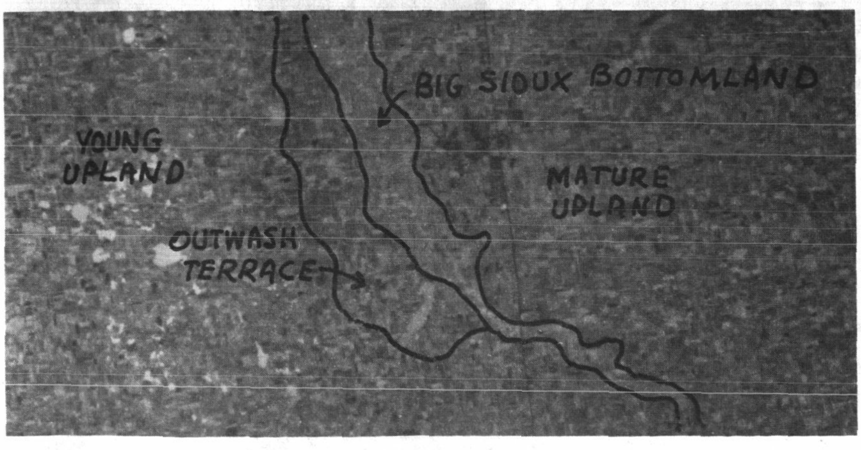
Bottomland, Terrace and Upland

Negative Prints, Scale 1:500,000, Eastern South Dakota

On this 17 June 1973 scene the boundaries of a bottomland, an outwash terrace, and two glacial uplands are apparent on MSS-5. The distinguishing features include reflective differences shown in gray tones, regularity of field patterns, presence or absence of streams, presence or absence of lakes and marshes. The last named feature is also seen on MSS-7. The reflective differences apparent between the poorly drained bottomland and the well drained terrace are due to the high incidence of grass vegetation on the bottomland which is near the peak of growth on 17 June. The higher lying terrace has well drained soils and is used exclusively as cropland. The west-lying glacial upland is dotted with marshes and lakes while the east-lying glacial upland has no lakes but instead has a stream drainage network.



MSS-7



MSS-5

Figure 7

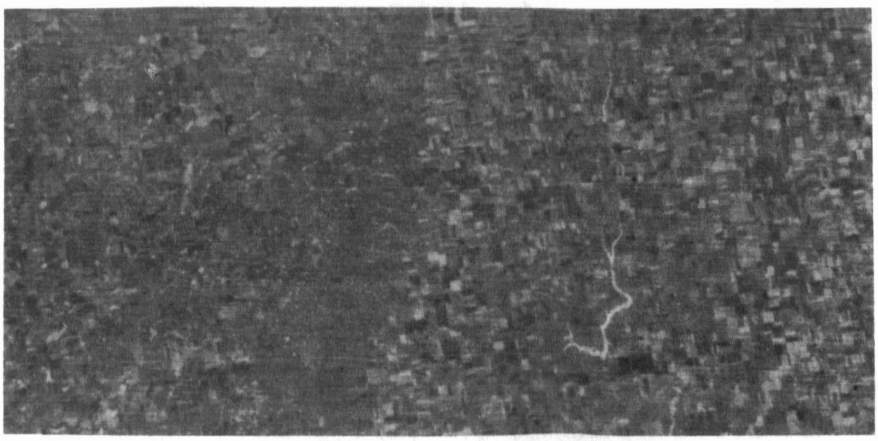
Use of ERTS 1 to identify Soil Association boundaries due to soil parent material differences

Dead-Ice Glacial Moraine, End Moraine, Ground Moraine

Negative Prints, Scale 1:500,000, Northcentral S. D.

On this 1 June 1973 scene the boundaries separating three kinds of soil parent materials are distinct on both MSS 7 and 5. The slight haze present however, was not penetrated as well by the MSS-5 as by the MSS-7 wavelengths resulting in a sharper image for the latter. The distinctness of the boundaries separating these soil parent materials is due to 1) unique land and water patterns of the strongly undulating Dead-Ice area seen especially well on MSS-7; 2) the uniform gray band of the steep, stony end moraine; and 3) the regular field pattern almost uninterrupted by lakes or grassed areas of the ground moraine.

MSS-7



MSS-5

Figure 8

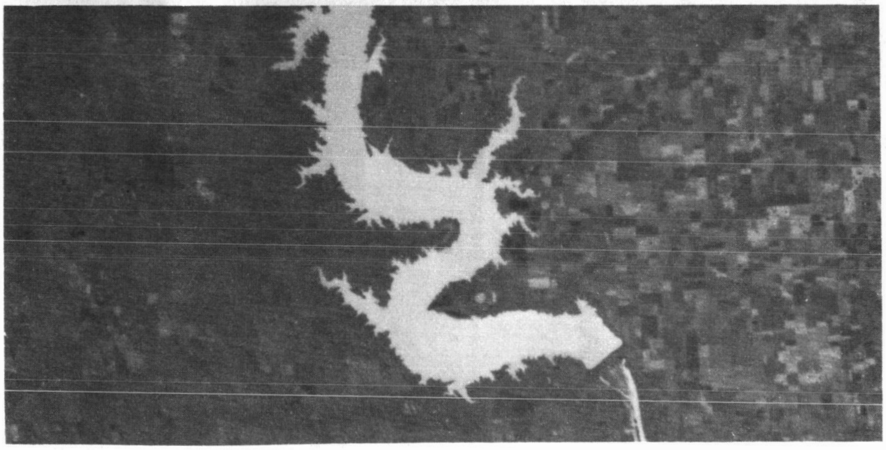
Use of ERTS 1 to distinguish Soil Association boundaries due to soil parent materials

Residual and Glacial Soil Association-Landscapes

Negative Prints, 15 May '73 Scale 1:500,000, Central South Dakota

The Oahe reservoir in central South Dakota occupies the trench of the Missouri River. East of this trench are friable medium textured glacial soil parent materials on a gently undulating surface having morainic depressions, marshes and lakes. West of the trench are firm clayey soil parent materials on a rolling surface characterized by broad ridges, steep valley sides and stream courses. The clayey residual soils on strong slopes are used primarily for rangeland, while the friable medium textured soils on gently undulating surfaces are mostly cropped to winter and spring wheat and corn.

MSS-7



MSS-5

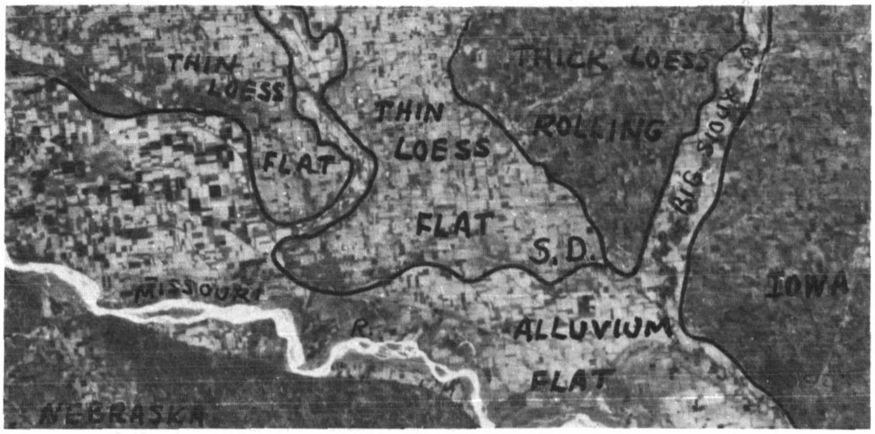
Figure 9

Use of ERTS 1 to identify Soil Association boundaries due to soil parent material differences

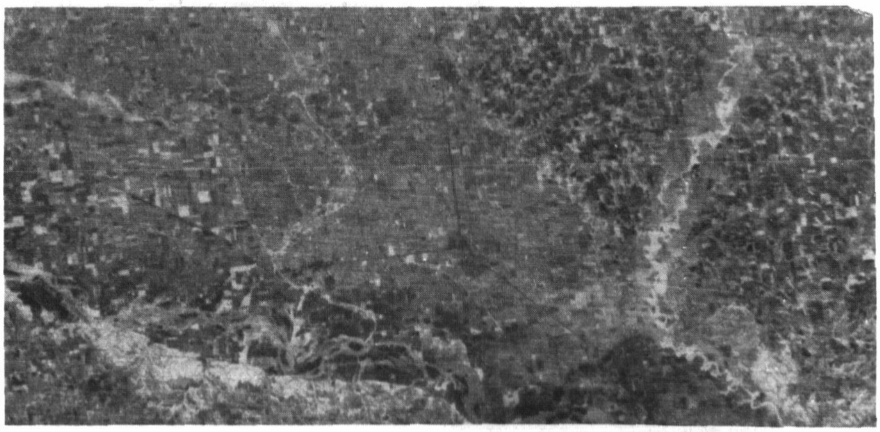
Loess and Alluvium

Negative prints, Scale 1:500,000, Southeast South Dakota

On this 17 June 1973 scene boundaries between two loess areas are apparent on both MSS 5 and 7. In addition, the alluvial area boundaries are distinct on MSS-7 from the thick loess area having rolling relief. The thin loess area having flat relief and the alluvial plain have similar reflectances. The agricultural land use in southeast South Dakota consist of raising corn and soybeans and some alfalfa and small grains on flat or nearly level soils while close-growing crops like small grains dominate steeper slopes. On 17 June the small grains are near their peak at vegetative growth thus reflecting strongly on MSS-7 while the flats having more corn and soybeans have soil exposed over much of the area (as these crops were planted only about a month earlier) and have low reflectance. An August scene would show reverse reflectances as the areas having more corn and soybeans would give higher reflectance than the associations with more small grain.



MSS-7



MSS-5

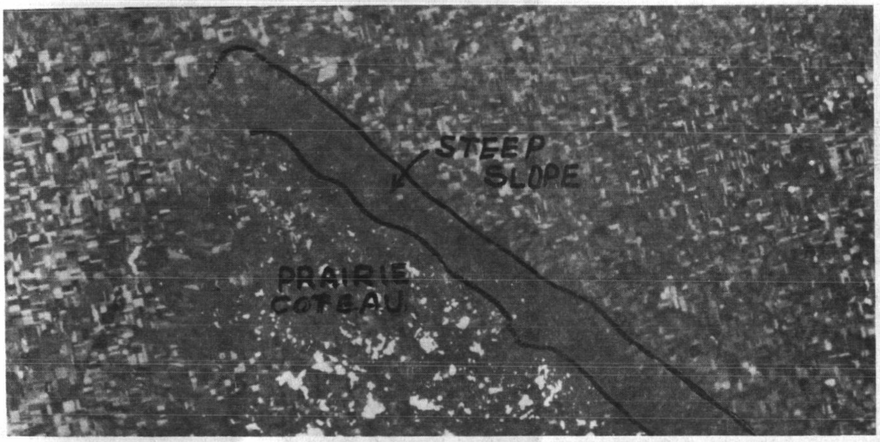
Figure 10

Use of ERTS 1 to distinguish Soil Association boundaries due to topography

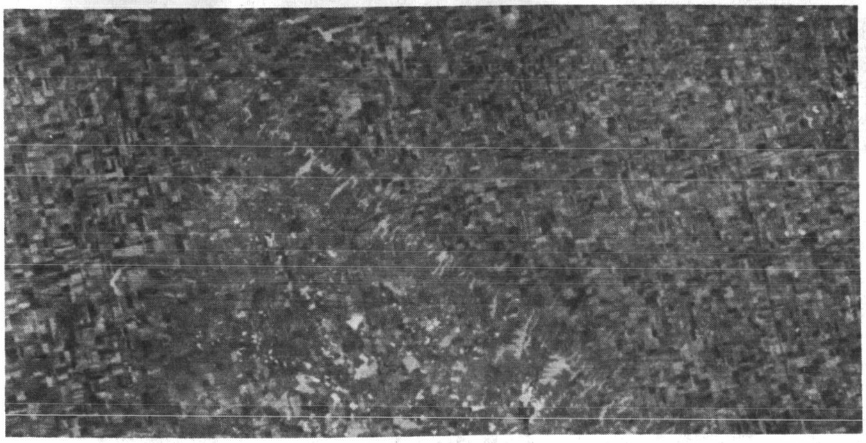
Glacial Area, Eastern South Dakota

Negative Prints, Scale 1:500,000,

On these July '72 prints the steep, escarpment of the Prairie Coteau stands out on MSS-7 as a broad dark band with distinct boundaries. This area is in grass because of its rugged topography and stoniness. On 29 July this grass is growing vigorously and hence reflects highly on MSS-7. On the Coteau lighter tones are prominent accentuated by many lakes on the crest of the Coteau. The lower-lying areas east and west of the Prairie Coteau have a field pattern indicating intensive cultivation. The light-toned fields shown on MSS-7 in this area have recently been planted to corn which has not grown enough at this time to have much reflectance on MSS-7. The steep slope is marked on MSS-5 by closely spaced parallel drains.



MSS-7



MSS-5

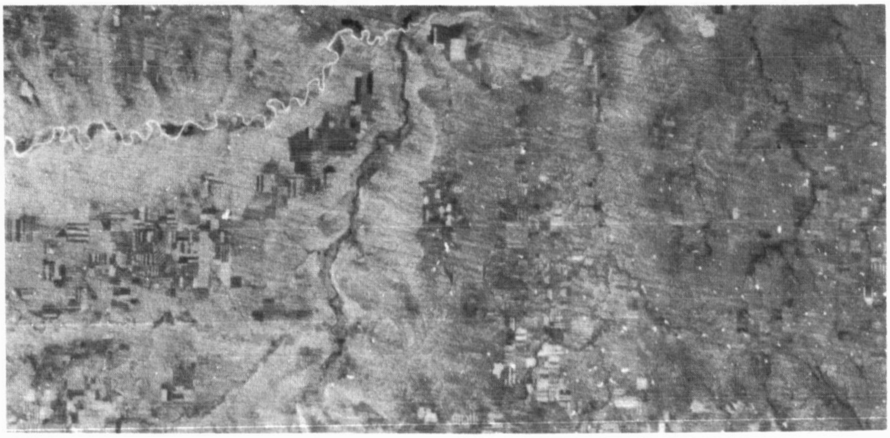
Figure 11

Use of ERTS 1 to distinguish Soil Association boundaries due to topography

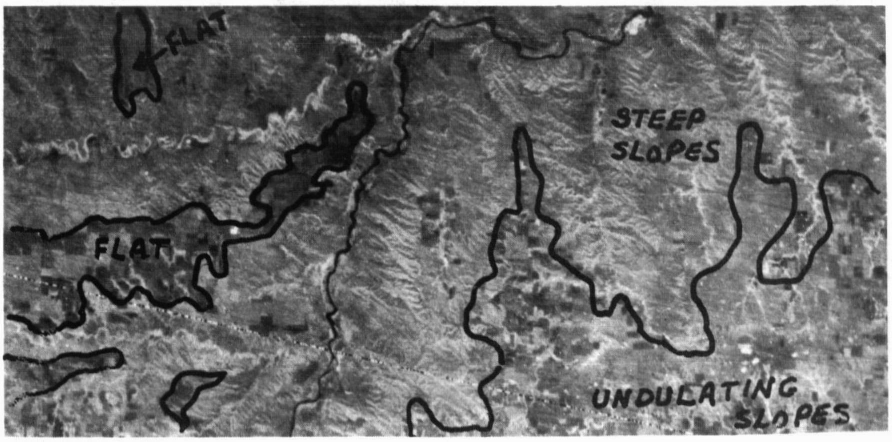
Residual Area, Western South Dakota

Negative prints, Scale 1:500,000

On these 9 July 1973 prints the steep valley sides of the Cheyenne and Belle Fourche rivers stand out with distinct boundaries on both MSS-5 and 7 from the adjacent less sloping areas. These steep areas, exclusively in grass, have thin clay soils derived from shale and produce less vegetation than the deeper, more friable soils occurring on less steep topography. Thus they have a reflective difference apparent on MSS-7 and this reflective difference correlates with the topographic boundary. On MSS-5 the reflective difference between the steep and less steep areas is less pronounced but the closely spaced stream network of the valley sides is more sharply etched, thus both MSS-5 and 7 aid it distinguishing the steep valley side boundaries.



MSS-7



MSS-5