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MAPPING SOILS, CROPS, AND RANGELANDS BY MACHINE ANALYSIS OF MULTI-TEMPORAL ERTS-1 DATA

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ABSTRACT

ERTS-1 data, obtained during the period 25 August 1972 to 5 September 1973 over a range of test sites in the Central United States, have been used for identifying and mapping differences in soil patterns, species and conditions of cultivated crops, and conditions of rangelands. Multispectral scanner data from multiple ERTS passes over certain test sites have provided the opportunity to study temporal changes in the scene.

Geometric correction was performed on the digital data for several dates and for several test sites. This made much easier the task of locating specific data points and of comparing the analytical results with other maps and data sources.

Multispectral classifications delineating soils boundaries in different test sites compared well with existing soil association maps prepared by conventional means.

Spectral analysis of ERTS data was used to identify, map, and make areal measurements of wheat in western Kansas.

Multispectral analysis of ERTS-1 data provided patterns in rangelands which can be related to soils differences, range management practices, and the extent of infestation of grasslands by mesquite (Prosopis fuliflora) and juniper (Juniperus spp.)

INTRODUCTION

Results of the analysis and interpretation of ERTS-1 multispectral data obtained over several Great Plains test sites on multiple dates are presented in this paper. These test sites were selected because they present a variety of problems associated with the development and management of land resources in the Great Plains.

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The purpose of the studies reported here is to examine the utility of ERTS-1 data and machine processing techniques in (1) identifying winter wheat and measuring its areal extent, (2) delineating soil association boundaries, (3) characterizing and mapping rangeland conditions, and (4) inventorying land use in a semiarid region.

Identification and Areal Measurement of Winter Wheat

Hard red winter wheat (Triticum vulgare) is the principal crop in Greeley County, Kansas. This area in western Kansas is typical of much of the winter wheat belt of the United States. ERTS-1 digital data obtained on 19 June 1973 were analyzed to separate wheat from other cover types and to measure the area in wheat.

On 14 May 1973 color and color infrared photography was obtained by a NASA aircraft at an altitude of 9500 m along a north-south flightline centered over Greeley County. By photo-interpretation of the color infrared photography three cover types were identified: wheat, fallow (bare soil) and permanent pasture. Training sets representing each of these three cover types were selected.

Using a clustering algorithm the ERTS-1 data for the area along the aircraft flightline were separated into eight spectrally separable classes in order to enhance the field boundaries. It was then possible to locate in the ERTS data the training fields selected from the aerial photography. A supervised algorithm was then used to classify the entire county into three categories: wheat, fallow, and pasture (Figure 1). A set of test fields was selected from the aerial photography and used to evaluate the classification results. Later the computer classification results of several fields were verified by the cooperative agricultural extension agent in Greeley County.

The classification accuracy is recorded in Table 1.

Table 1. Results of Computer Classification of ERTS-1 MSS Data, Greeley County, Kansas, 19 June 1973.

Class	% Correct Recognition of Tested Fields*
Pasture	96.1
Wheat	97.0
Fallow	97.9

*From underflight photography and limited ground observations.

From the classification results the area of wheat in Greeley County was then calculated, and the results were compared with estimates made by the Statistical Reporting Service (U.S. Department of Agriculture). These comparisons are presented in Table 2.

Table 2. 1973 Wheat Area Estimates for Greeley County, Kansas.

Source of Estimate	Hectares
SRS (USDA)	73,000 ± 5%
ERTS	77,000

Delineation of Soil Associations

One of the important uses of ERTS imagery is in the delineation of soil associations or groups which may have different physical and chemical properties. The Soil Conservation Service (U.S. Department of Agriculture) is vitally concerned with the classification and mapping of soils, with the use and management of soils, and with the monitoring of changing land uses. Digital data from ERTS-1 have been studied to determine their application in each of these concerns of SCS.

The soil association map (Figure 2) of Crosby County, Texas, shows the northern one-third of the county to consist of deep clays and silty clay loams. The soils in the central part of the county west of Blanco Canyon are mixed lands--silt loams and silty clay loams. To the south of this area the soils grade into the lighter sandy loams. The soil association map shows in the southwest part of the county on the High Plains an area of deep sandy soils. The Caprock Escarpment separates the soils of the High Plains from the soils of the Rolling Plains. Just below the rim of the Escarpment is a band of steep shallow soils. As the slopes flatten out below the Escarpment sandy loams predominate. However, there are two areas of deep sands in the southeast part of the county.

An examination of an image (Figure 3) of Crosby County produced from bands 4, 5, and 7 of the 9 October 1972 ERTS pass reveals rather well the gross soil patterns, including the clearly defined Caprock Escarpment. Using all four bands of the 9 October 1972 ERTS MSS data a nonsupervised or clustering algorithm was used to produce a classification with fourteen spectral classes (Figure 4). Examination of the patterns reveals subtle changes which correspond to the changes in soils from the heavy clay soils in the north to the sandy loams and sands in the south and southeast.

Fourteen spectral classes produced with MSS data from the 2 December 1972 ERTS pass reveal similar soil changes from north to south (Figure 5). In the 12 spectral classes produced from the 18 June 1973 ERTS MSS data the soils patterns seem to be less distinct (Figure 6). However, the Caprock Escarpment and the deep sands are easily delineated.

A closer view of the 9 October and 2 December spectral classifications of the Blanco Canyon area east of Crosbyton reveals the sharp break between the High and Rolling Plains (Figures 7 and 8). There are also subtle spectral differences which relate to the steep shallow soils and the less steep, rolling sandy soils between the Caprock Escarpment. In the immediate future data from these three dates will be geometrically corrected so that temporal overlay analysis can be done. At that time a soil association map will be produced with the use of ERTS imagery as a base.

Characterizing and Mapping Rangeland Conditions

To a very large degree man is dependent upon the rangelands in the arid and semiarid regions of the world for producing animal protein. The task of monitoring and managing these rangelands is great. Millions of hectares of rangeland in the Western United States are subject to overgrazing and mismanagement. Temporal data from ERTS can provide very useful information and monitoring services for private organizations and public agencies whose responsibility it is to manage rangelands.

A spectral classification of an area around the T Bar Ranch in Lynn County, Texas was produced from ERTS MSS data obtained on 9 October 1972 (Figure 9). The purpose of the classification was to delineate spectrally different conditions of rangelands. Although it is difficult to quantify the results, an examination of low altitude aerial photography indicates that a good separation has been obtained between three conditions: (1) range grasses, (2) a mixture of grasses and mesquite (*Prosopis fuliflora*) and (3) heavy mesquite infestation (Figure 10).

An area of rangeland in the southeastern part of Crosby County around the White River Reservoir was also examined. Images produced from ERTS MSS bands 4, 5, and 7 and classifications using all 4 MSS bands were generated from the 18 June 1973 ERTS MSS data. The image (Figure 11) indicates where the more dense green vegetation is located and delineates the rangeland from the cultivated fields. The classification (Figure 12) suggests where the heavy vegetation and more uniform areas are. It also illustrates the mottled area west of the White River Reservoir which seems to be related to differences in topography, soil productivity, soil depth, and vegetative cover.

Land Use Inventory in Semiarid Region

In the coming decade the United States may be challenged as never before in the tasks of land management and agricultural production. Permanent vegetation on millions of hectares of marginal land is now being sacrificed to the plow. Lands which are highly susceptible to wind and water erosion are being brought under cultivation to take advantage of the record high prices for agricultural products. Changing land use patterns call for faster and more accurate methods of monitoring land use change.

MSS data from two ERTS passes over Lubbock County, Texas have been studied. The dates are 2 December 1972 and 18 June 1973.

Images produced from ERTS MSS bands 4, 5, and 7 for these two dates reveal some striking differences (Figures 13 and 14). In December the urban and rural scenes are easily separated. However, the scarcity of green vegetation subdues the spectral differences between different features in both urban and rural areas. In the June image differences in green vegetation present more contrast and enhance the separability between parks, residential areas, and commercial-industrial zones in the city of Lubbock.

A computer-generated classification of the June data for Lubbock County (Figure 15) illustrates spectral classes related to rural lands, urban residential, commercial-industrial, and water.

A closer look at the city of Lubbock reveals more clearly the differences between the two dates (Figures 16 and 17). In the image for June the residential areas are easily delineated from the commercial-industrial areas and the major transportation arteries. The classification (Figure 18) is a map of the city illustrating five spectral classes--residential, commercial-industrial, water, dense green areas (parks, grass), and rural (non-green fields).

Many features identified on aerial photography can be identified in the classification of the ERTS data. Two examples are the Lubbock Airport (Figure 19) and the large complex of cotton warehouses southeast of Lubbock (Figure 20).

The most recent updating of the Lubbock City map was in 1971. A careful comparison of the classification of ERTS data and the city map reveals many areas of land use change on the outskirts of the city since 1971.

Conclusions

Results reported in this paper strongly support the need for an operational satellite for observing, mapping, and monitoring earth resources. In the opinions of the authors of this paper the feasibility has been established for using satellite-acquired multispectral scanner data and computer-implemented pattern recognition techniques to identify and measure area of crops, to assist in mapping soils, to characterize and monitor rangeland conditions, and to prepare and update land use inventories.

ATTACHMENT A

ERTS Data Analyzed

Test Site	ERTS-1 Scene I.D.	Date of Pass
Greeley County, Kansas	1331-16571	19 June 1973
Crosby County, Texas	1078-16524	9 Oct 1972
Crosby County, Texas	1132-16532	2 Dec 1972
Crosby County, Texas	1330-16531	18 June 1973
Lubbock County, Texas	1132-16532	2 Dec 1972
Lubbock County, Texas	1330-16531	18 June 1973
Lynn County, Texas	1330-16531	18 June 1973

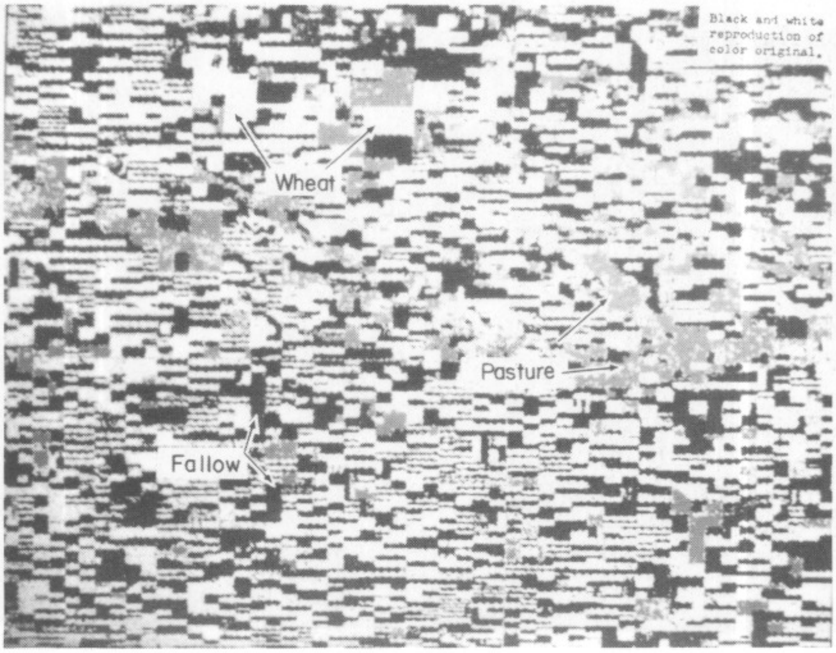

Figure 1. Identification of wheat, fallow (bare soil), and permanent pasture in Greeley County, Kansas by computer analysis of multispectral scanner data from the 19 June 1973 ERTS pass.

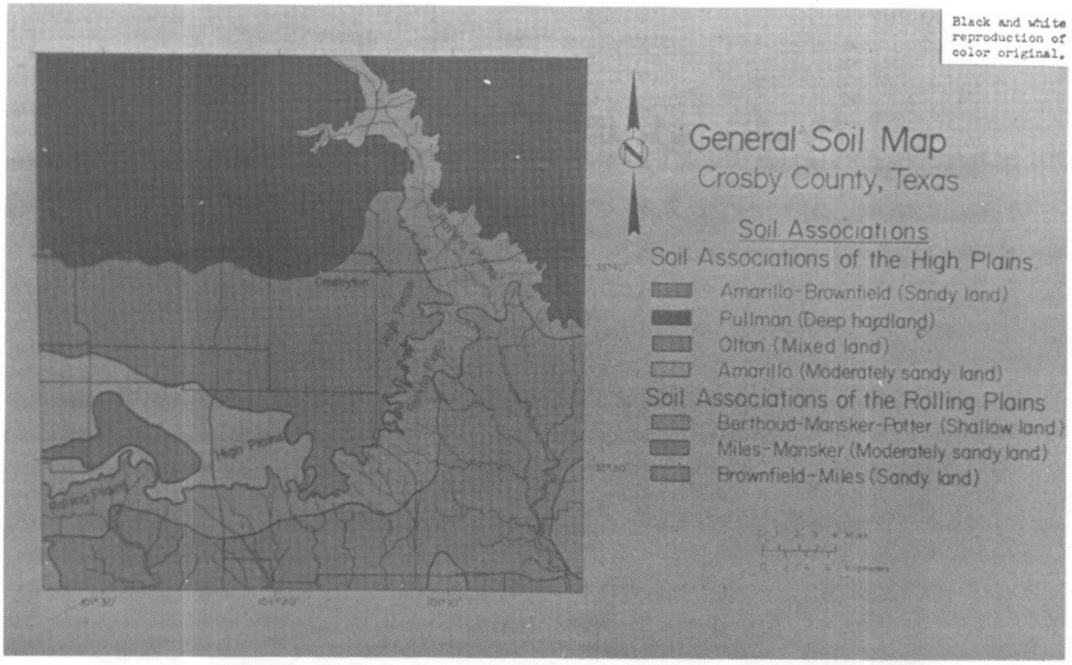

Figure 2. Soil association map of Crosby County, Texas.

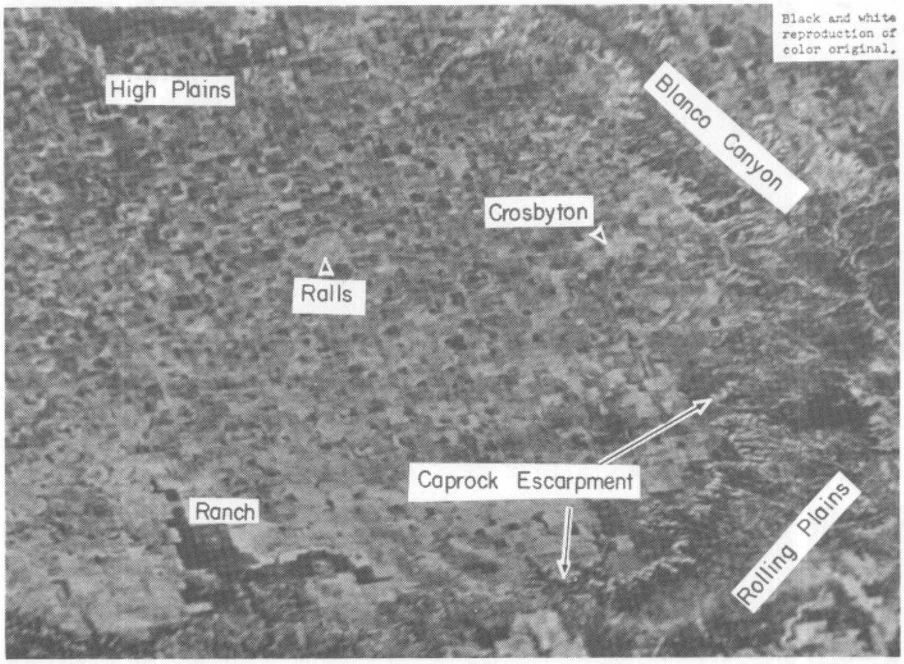

Figure 3. Image of Crosby County, Texas produced by computer analysis of MSS data from 9 October 1972 ERTS pass.

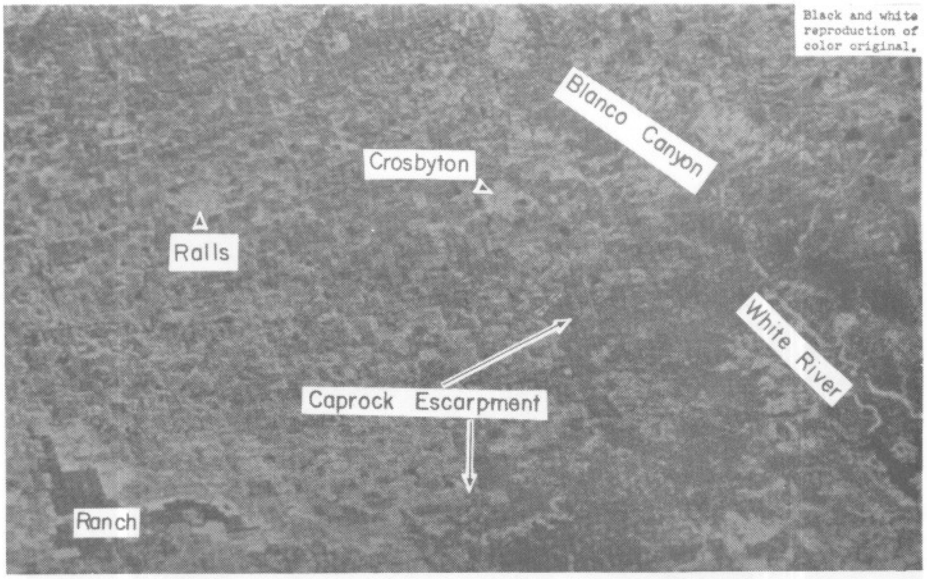

Figure 4. Fourteen spectral classes (representing different ground cover types or conditions in Crosby County, Texas) produced by computer analysis of MSS data from the 9 October 1972 ERTS pass.

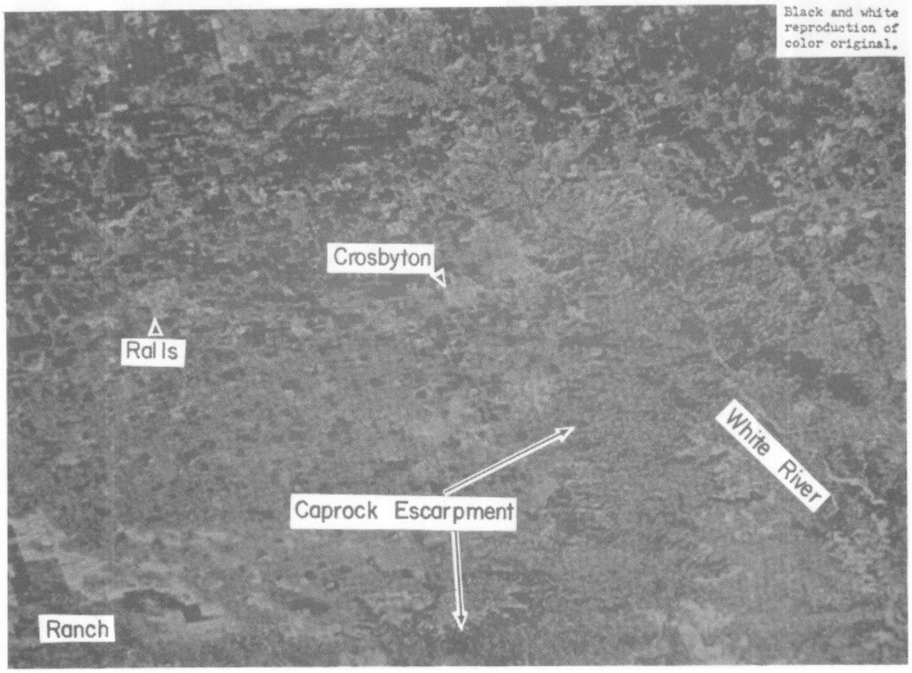

Figure 5. Fourteen spectral classes produced by computer analysis of MSS data from the 2 December 1972 ERTS pass over Crosby County, Texas.

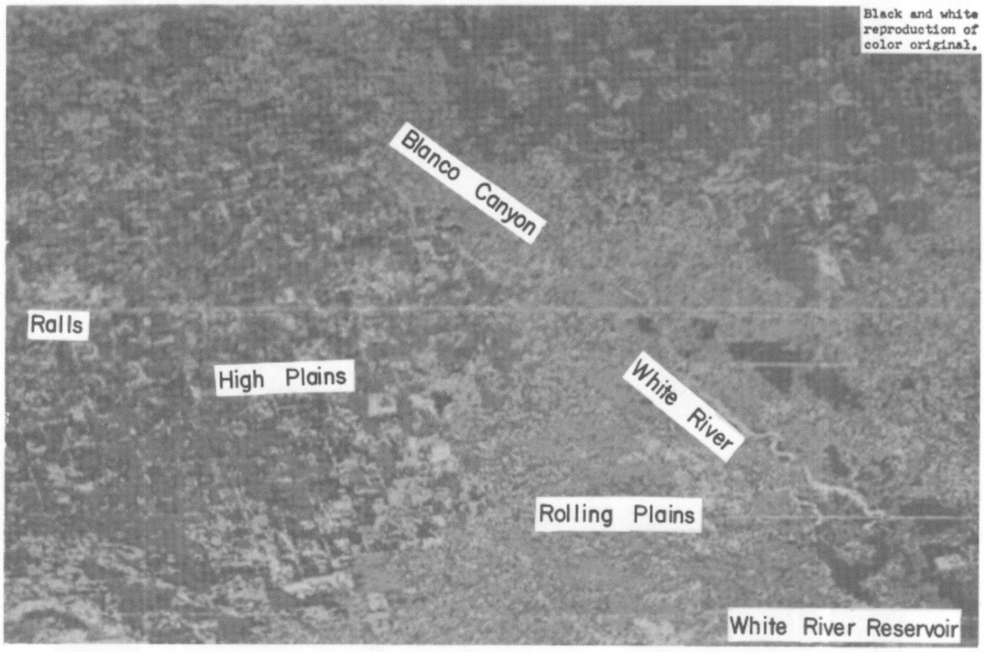

Figure 6. Twelve spectral classes produced by computer analysis of MSS data from the 18 June 1973 ERTS pass over Crosby County, Texas.

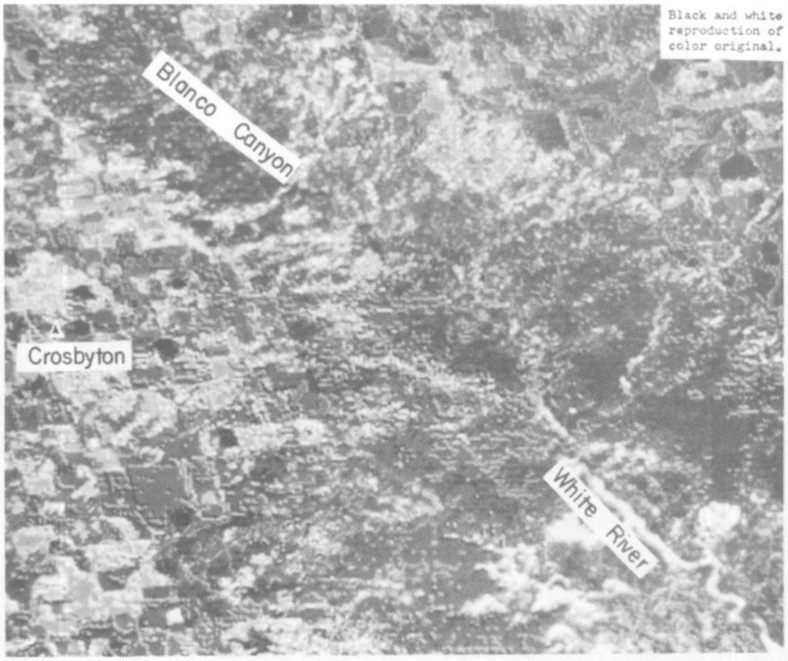

Figure 7. Fourteen spectral classes of Blanco Canyon area east of Crosbyton, Texas; produced from 9 October 1972 ERTS data.

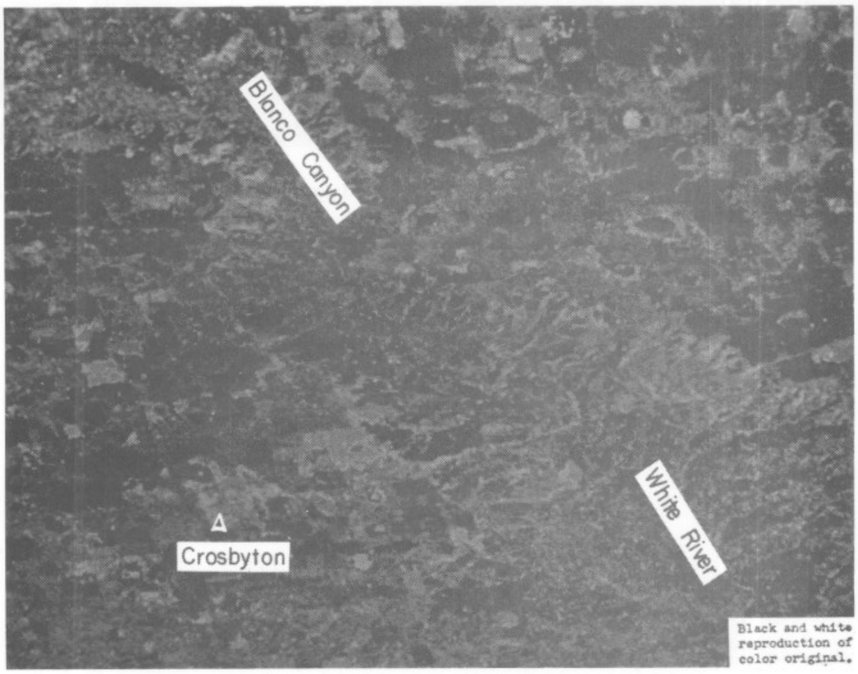

Figure 8. Fourteen spectral classes of Blanco Canyon area east of Crosbyton, Texas; produced from 2 December 1972 ERTS data.

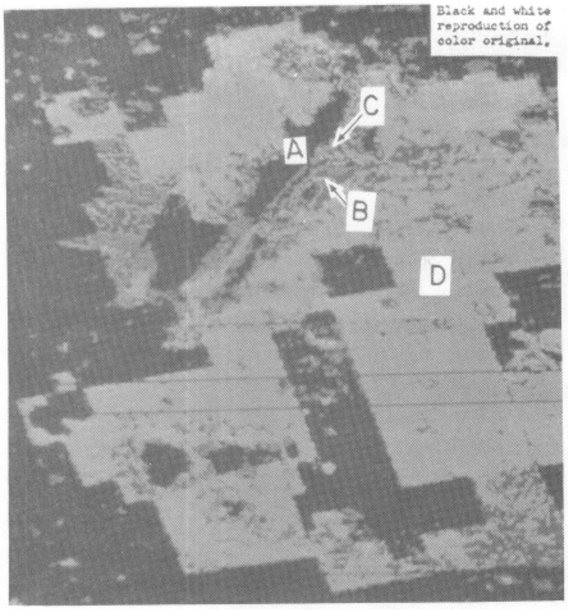

Figure 9. Four spectral classes of T Bar Ranch area in Lynn County, Texas, produced from 18 June 1973 ERTS data; A = Double Lakes; B = heavy mesquite infestation; C = moderate mesquite infestation; D = little or no mesquite infestation.

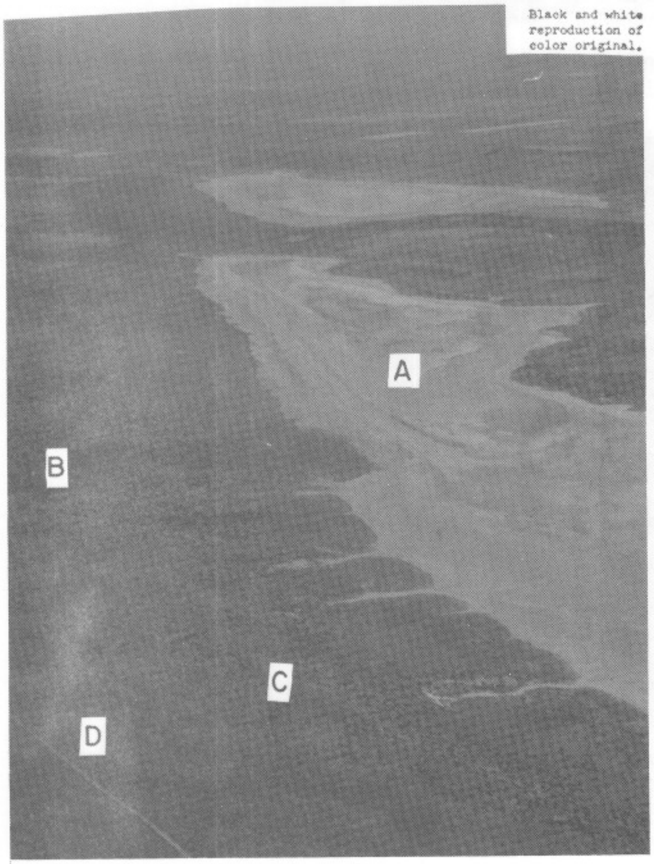

Figure 10. Aerial photograph taken over T Bar Ranch on 5 July 1973; A = Double Lakes; B = heavy mesquite infestation; C = moderate mesquite infestation; D = little or no mesquite infestation.

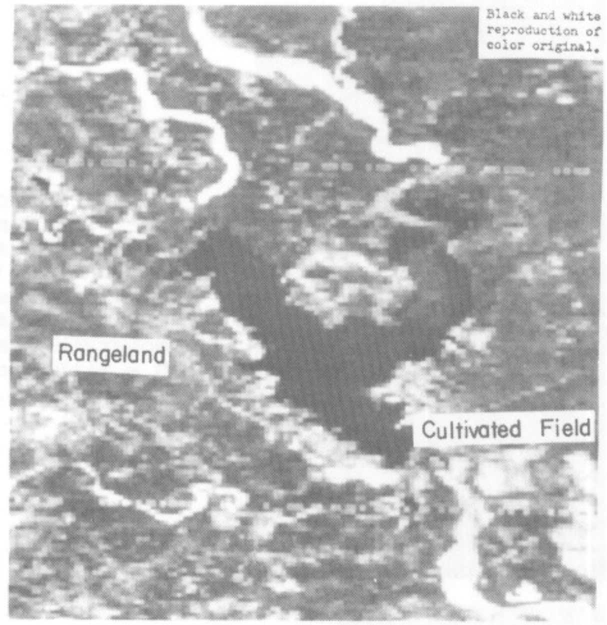

Figure 11. Image of White River Reservoir area produced by computer analysis of MSS data obtained from 18 June 1973 ERTS pass.

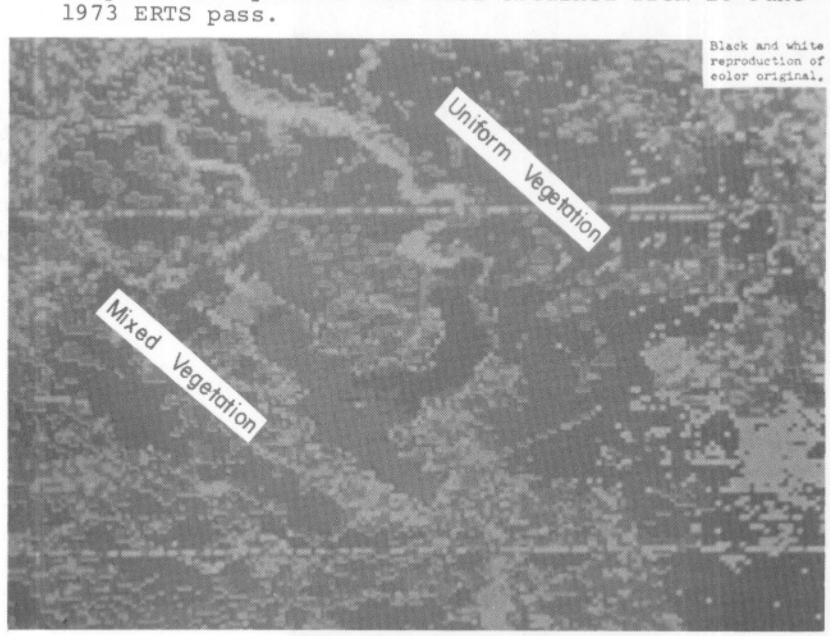

Figure 12. Nine spectral classes of White River Reservoir area in Crosby County, Texas; produced from 18 June 1973 ERTS data.

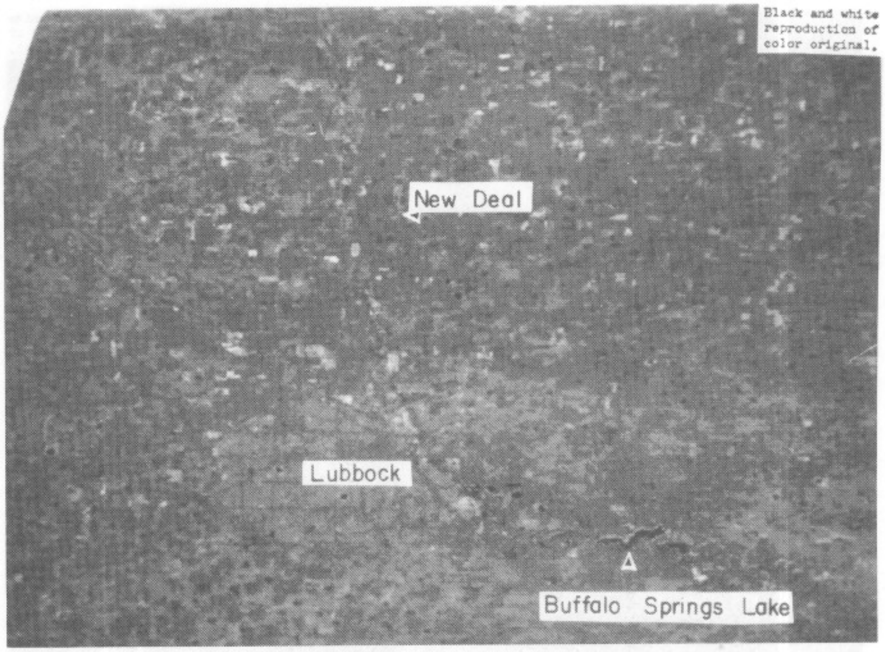

Figure 13. Image of Lubbock County, Texas produced by computer analysis of MSS data obtained from 2 December 1972 ERTS pass.

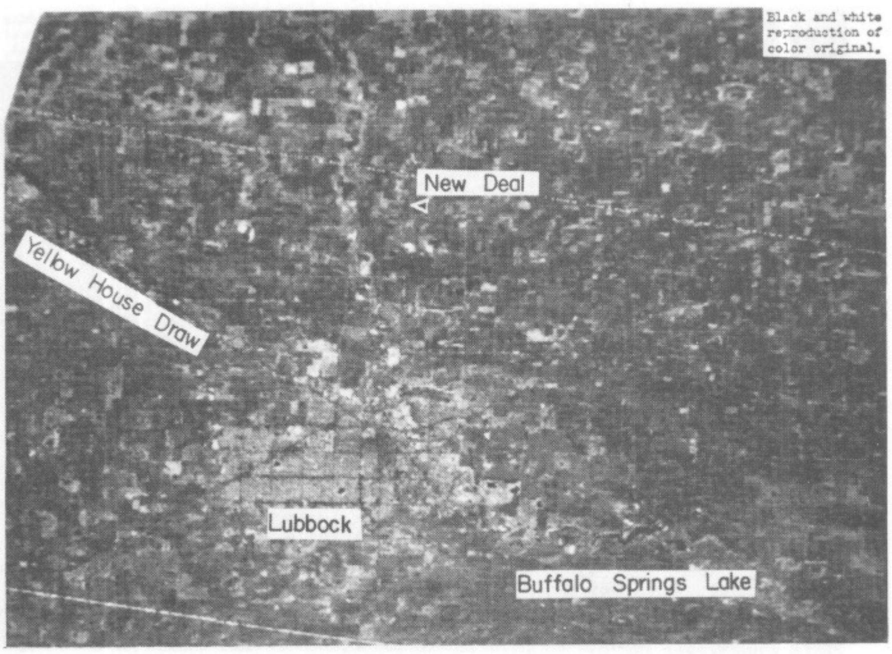

Figure 14. Image of Lubbock County, Texas produced by computer analysis of MSS data obtained from 18 June 1973 ERTS pass.

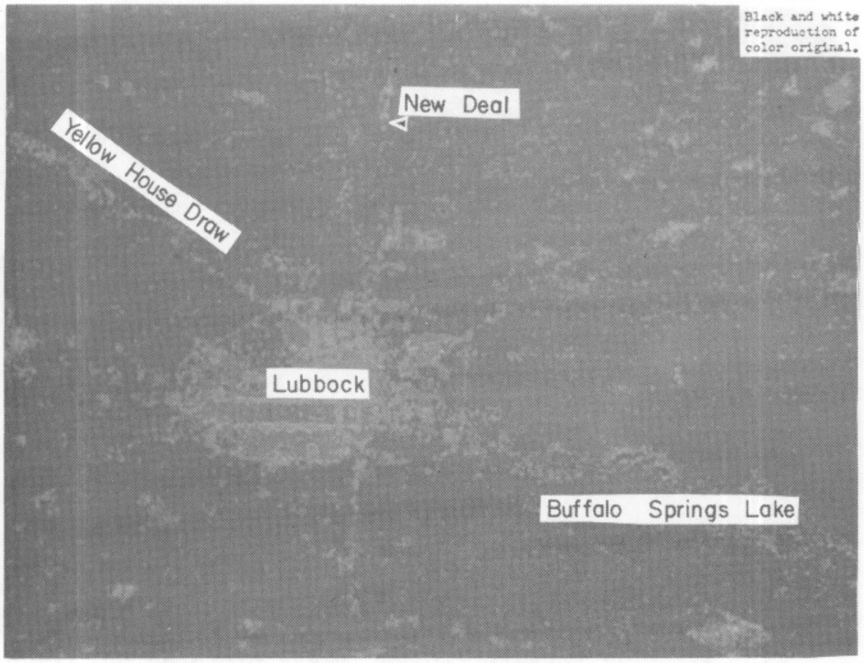

Figure 15. Four spectral classes of Lubbock County, Texas; produced from 18 June 1973 ERTS data.

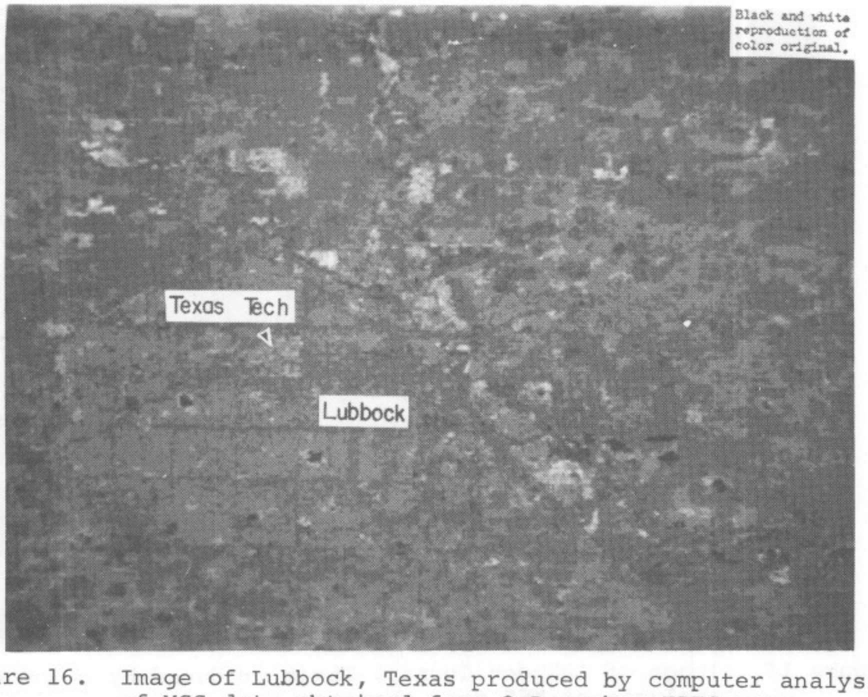

Figure 16. Image of Lubbock, Texas produced by computer analysis of MSS data obtained from 2 December ERTS pass.

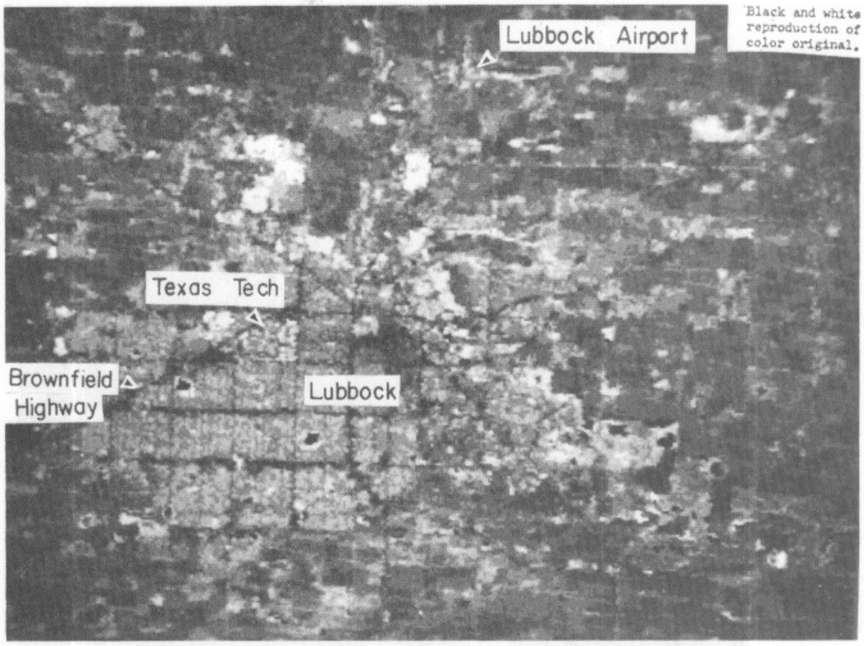

Figure 17. Image of Lubbock, Texas produced by computer analysis of MSS data obtained from 18 June 1973 ERTS pass.

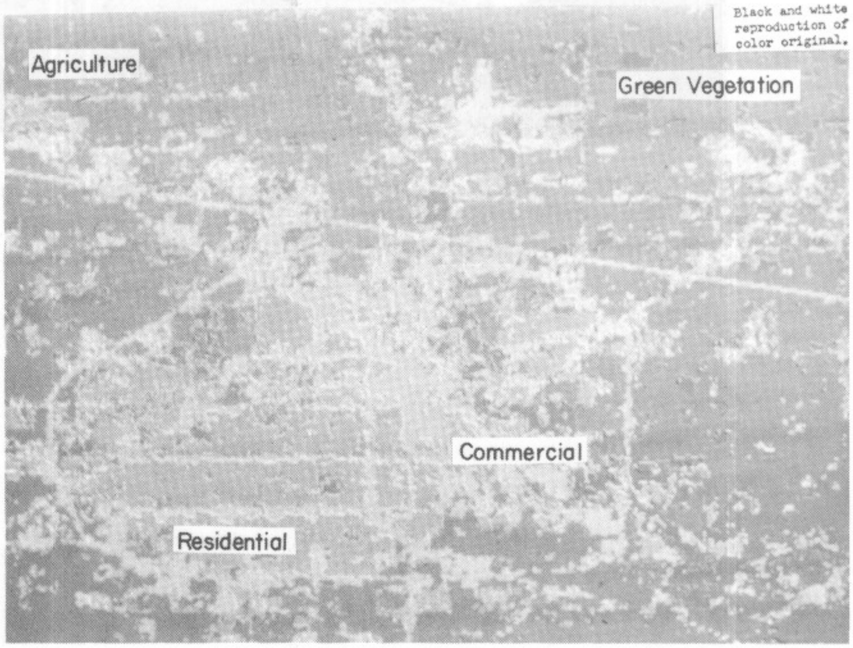

Figure 18. Four spectral classes of Lubbock, Texas area; produced from 18 June 1973 ERTS data.

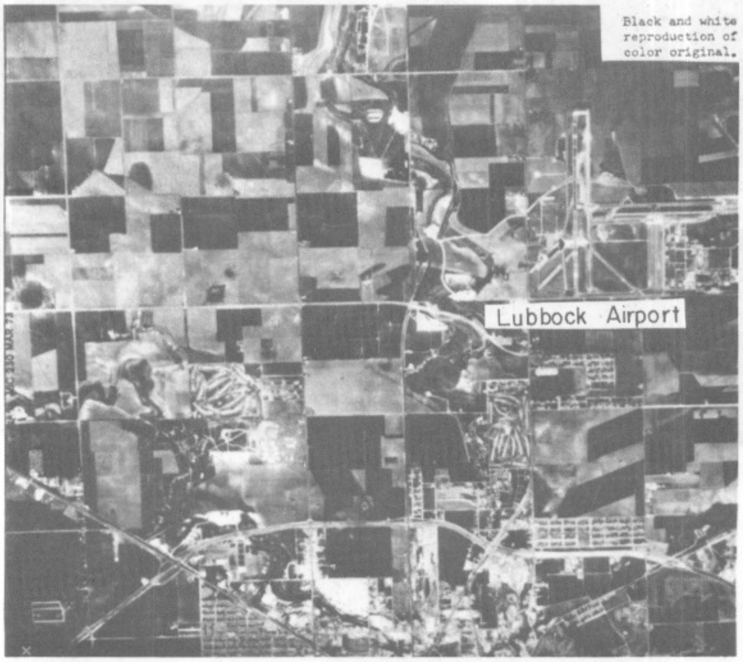

Figure 19. Aerial photograph taken on 20 March 1973 north of Lubbock, Texas.

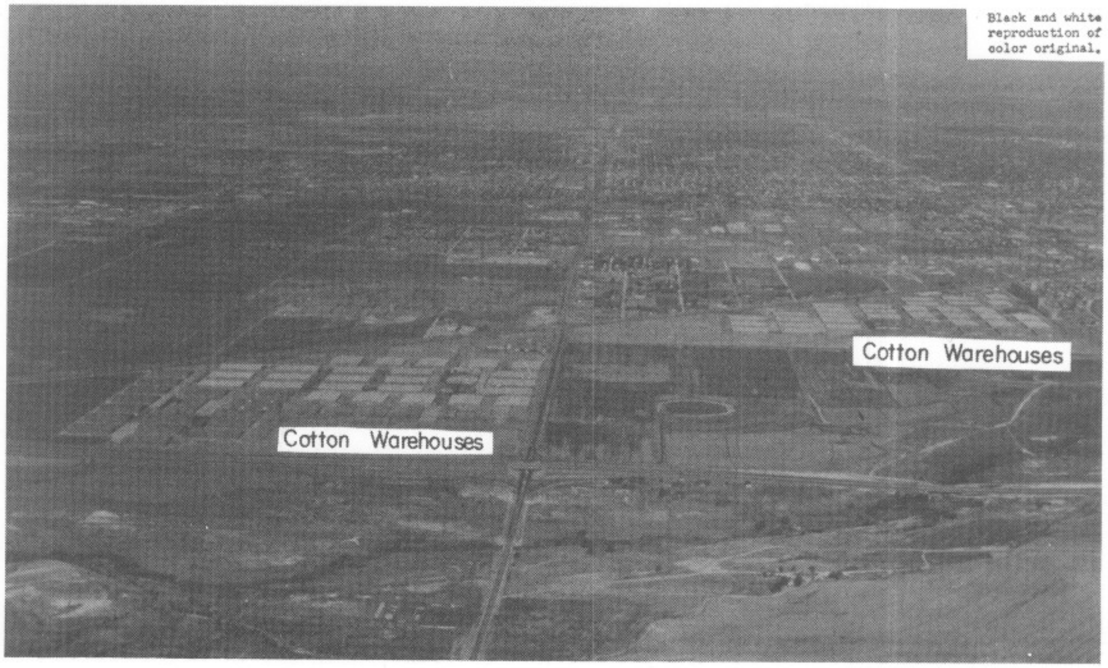

Figure 20. Oblique aerial photograph taken on 5 July 1973 over southeast Lubbock, Texas.