MAPPING AND MEASURING LAND-COVER CHARACTERISTICS OF NEW RIVER BASIN, TENNESSEE, USING LANDSAT DIGITAL TAPES

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-106

Prepared in cooperation with the

U.S. Soil Conservation Service

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.

4. Title and Subtitle
MAPPING AND MEASURING LAND-COVER CHARACTERISTICS OF NEW RIVER BASIN, TENNESSEE, USING LANDSAT DIGITAL TAPES

5. Report Date
September, 1976

6.

7. Author(s)
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8. Performing Organization Rept. No. USGS/WRI-76-106

9. Performing Organization Name and Address
U.S. Geological Survey, Water Resources Division
A-413 Federal Building
U.S. Courthouse
Nashville, TN. 37203

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
U.S. Geological Survey, Water Resources Division
A-413 Federal Building
U.S. Courthouse
Nashville, TN. 37203

13. Type of Report & Period Covered
Interim

14.

15. Supplementary Notes
Prepared in cooperation with the U.S. Soil Conservation Service.

16. Abstracts
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17. Key Words and Document Analysis. 17a. Descriptors
*Remote sensing, *Satellites (artificial), *Maps, *Land use, *Distribution patterns, *Strip mines, Forests, Data processing, Terrain analyses, Land classification, Watersheds (basins), Sediments, Coal mines, Small watersheds.

17b. Identifiers/Open-Ended Terms
*Basin characteristics, *Landsat digital tapes, Multispectral analysis, Cumberland Plateau, Tennessee, Bare earth.

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution.	UNCLASSIFIED	20 pages
	20. Security Class (This Page) UNCLASSIFIED	22. Price

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UNITED STATES DEPARTMENT OF THE INTERIOR

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OPEN-FILE REPORT

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MAPPING AND MEASURING LAND-COVER CHARACTERISTICS OF NEW RIVER BASIN, TENNESSEE USING LANDSAT DIGITAL TAPES

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ABSTRACT

Land-cover information is needed to select subbasins within the New River basin, Tennessee, for the study of hydrologic processes and also is needed to transfer study results to other sites affected by coal mining. It was believed that data recorded by the first Earth Resources Technology Satellite (Landsat-1) could be processed to yield the needed land-cover information. This study demonstrates that digital computer processing of the spectral information contained in each picture element (pixel) of 1.1 acres (4,500 m^2) can produce maps and tables of the areal extent of selected land-cover categories.

The distribution of water, rock, agricultural areas, evergreens, bare earth, hardwoods, and uncategorized areas, is portrayed on a map of the entire New River basin (1:62,500 scale) and on 15 quadrangles (1:24,000 scale). Although some categories are a mixture of land-cover types, they portray the predominant component named. Tables quantify the area of each category and indicate that agriculture covers 5 percent of the basin, evergreens cover 7 percent, bare earth covers 6 percent, three categories of hardwoods cover 81 percent, and water, rock, and uncategorized areas each cover less than 1 percent of the basin.

CONVERSION FACTORS

Factors for converting English units to metric units are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the English units.

English	Multiply by	Metric
acres	4.047×10^{-3}	m^2 (square metres)
	4.047×10^{-3}	km^2 (square kilometres)
ft (feet)	3.048×10^{-1}	m (metres)
mi^2 (square miles)	2.590	km^2 (square kilometres)
tons (short)	9.072×10^{-1}	t (metric tons or tonnes)

INTRODUCTION

THE PROBLEM AND OBJECTIVES OF STUDY

The Tennessee Division of Geology, the U.S. Soil Conservation Service, and the U.S. Geological Survey started a project in 1974 to assess the impact of energy resource development on dissolved constituents in water, sediment production, and streamflow of New River and its tributaries. New River flows in a northwesterly direction and joins Clear Fork River to form Big South Fork Cumberland River, which flows north through a deep gorge that is being considered for development as a national recreation area. Sediment produced by coal mining in New River basin discharges to Big South Fork Cumberland River and makes the water very turbid. Little is known about the hydrology of the New River basin under natural conditions. Even less is known about the full impact of coal strip mining on the hydrology.

The cooperative project was designed to provide land-cover information that is needed to select subbasins for intensive study which would be representative of different degrees of mined, unmined, and reclaimed land. Land-cover information will be needed also to transfer the results of investigation of hydrologic processes from gaged to ungaged sites. The purpose of this report is to present the results of the cooperative effort between the Geological Survey and the U.S. Soil Conservation Service in mapping and measuring land cover in the New River basin.

BASIN PHYSIOGRAPHY, GEOLOGY, AND MINING

The New River basin is located within the Cumberland Plateau physiographic region in east-central Tennessee near the Tennessee-Kentucky state line (fig. 1, p. 8). The basin drainage area is 394 mi^2 (1,020 km^2) at the mouth where New River joins Clear Fork River. From this point at altitude 1,004 ft (306 m) the basin rises to the southeast to maximum altitude 3,534 ft (1,077 m) along the Tennessee River - Cumberland River drainage divide. Relief within any 5 mi^2 (13 km^2) area commonly exceeds 1,500 ft (460 m). In this basin the plateau is so dissected that sediment from strip mining can move rapidly downslope to a main channel.

The basin is underlain by nearly flat lying beds of shale, sandstone, siltstone, conglomerate, and coal of Pennsylvanian age whose aggregate thickness exceeds 3,000 ft (900 m). At least 39 coal seams have been identified in this section, but only seven seams are regarded as commercially important (Luther, 1960). These seams are classed as low-sulfur, bituminous coal. Although no carbonate rock units have been mapped within the basin, calcite may occur abundantly as an accessory mineral in some shales.

Coal was shipped first from the northern coal fields of Tennessee in the mid-1800's. By 1974, the three counties making up the New River basin produced 4.9 million tons (4.4 million metric tons) or 56 percent of the State's annual production, and production is increasing. Of the

1974 production, 70 percent was mined by contour stripping and (or) augering (Keystone, 1976).

PROCESSING LANDSAT TAPES

The intensity of sunlight reflected from the land surface is recorded in each 1.1 acre (4,500 m^2) pixel in the Landsat digital tapes. Differences in reflected light in four wavelength bands were analyzed and processed by the U.S. Geological Survey and Bendix Aerospace Systems Division under contract to the Survey to produce maps and tables of the areal extent of nine land-cover categories. Areas typical of each category were selected and examined in the field (fig. 2, p. 9). Landsat coordinates were matched to geographic coordinates. The typical areas were then located on the tapes and used to "train" the computer to recognize each category by using processing coefficients that were derived by a trial and error process from the intensity of light reflected from these training areas (Dye and Chen, 1975). The coefficients were tested, and when found satisfactory, they were used to categorize the entire basin. The geometrically-corrected, categorized data were transferred to film, enlarged to standard mapping scales, and color coded to produce maps. In addition, tabular printouts were produced containing the area of categories within the basin and also on each 7.5-minute quadrangle (fig. 3, p. 10) containing part of the basin. Areas were selected and examined by A. L. Higer and A. E. Coker, U.S. Geological Survey. Processing coefficients were derived by L. E. Reed, Bendix Aerospace and A. E. Coker. Further details on data processing may be found in a report to be entitled "The Application of Remote Sensing Technology to Assess the Hydrologic Effects of Coal Mining in Eastern Tennessee" being prepared by A. E. Coker, A. L. Higer, and S. P. Sauer (written communication, 1976).

LANDSAT MAPS

CATEGORY DEFINITIONS

Nine land-cover categories that are pertinent to the hydrology of New River basin were defined in this study (see fig. 4, p. 11). Examination of small-scale aerial photography and field reconnaissance reveals that numerous areas that are mapped as one of the following categories actually consist of the following land-cover types:

Uncategorized, less than 1 percent of New River basin, is largely rock and bare earth in strip mines in shadow on the northwest side of the mountains.

Water, less than one-tenth of 1 percent of the basin, consists of small lakes, strip-mine pools, and downstream reaches of New River.

Rock, less than 1 percent of the basin, is predominantly the rock highwalls in strip mined areas on the southeast side of the mountains. A small amount is very reflective fields in the agricultural areas in the northernmost third of the basin.

Agriculture, 5 percent of the basin, is predominantly crops, pasture, and some fallow ground. A moderate amount is actually highly-reflective evergreens in full sunlight on the southeast side of the mountains.

Evergreens, 7 percent of the basin, are predominantly native conifers.

Bare earth, 6 percent of the basin, is predominantly strip pit and spoil bank of coal strip mines. Mine-access roads, sediment bars along stream courses, and plowed fields also fall in this category.

Hardwood I, 14 percent of the basin, and Hardwood II, 12 percent of the basin, are similar deciduous tree associations which are related to the amount of sunlight striking the sides of the mountains. The Landsat imagery is recorded at 0930 CST. At this time of day, the steep, northwest-facing slopes are usually in shadow (Hardwood I) and the southeast-facing slopes are receiving almost perpendicular illumination (Hardwood II). Hardwood III, 55 percent of the basin, is predominantly deciduous forest under average lighting conditions. For most land-cover studies, the three hardwood categories could be combined as, simply, Hardwood. They are shown separately under the assumption that later studies might reveal a hydrologically significant difference in soil moisture and stormwater runoff associated with Hardwood I and Hardwood II.

Although some categories are a mixture of land-cover types, they portray the predominant component named. It is estimated that in 15 out of 16 sets of measurements corresponding with the maps each category is the component named, to the following accuracy:

Within 5 percent:
    Water, Evergreens, Bare earth, and Hardwood III
Within 10 percent:
    Agriculture, Hardwood I, Hardwood II
Within 15 percent:
    Rock
Greater than 15 percent:
    Uncategorized

CATEGORIZED MAPS

The map of the entire basin (fig. 4, p. 11) shows the distribution of the nine selected, land-cover categories. Agriculture occurs predominantly in the northern most third of the basin where there are more open valleys and less relief. Evergreens are distributed evenly throughout the basin and occur mostly along the steep-sided valleys of first-order streams. The bare-earth category predominantly depicts contour strip mining. Mining occurs mostly in the southeastern half of the basin, where natural erosion of the plateau has extensively exposed coal seams. Because Hardwood I and Hardwood II are related to the amount of sunlight striking the sides of mountains, they occur predominantly in the southeastern half of the basin where mountainous relief is greatest. Hardwood III, representative of deciduous forest under average illumination conditions, is predominantly found in the northwestern half of the basin.

The map of Fork Mountain quadrangle (fig. 5, p. 12) shows the distribution of the nine land-cover categories and is representative of

the 15 mapped quadrangles covering the basin. The relationship of each category to the topography and to the drainage can be seen easily. Agriculture is restricted to the flat part of major valleys. Evergreens border small streams. Rock and bare earth follow the contour of the mountains where coal was strip mined. Hardwood I is on the northwest side of the mountains, and Hardwood II is on the southeast side. At this scale (1:24,000 in the original), drainage divides for small basins can be located easily on the map. Because each pixel is only 1.1 acres (4,500 m^2) in size, the land cover in a basin only 5 mi^2 (13 km^2) can be characterized by as many as 2,900 data points.

The second map of Fork Mountain quadrangle (fig. 6, p. 13) shows the distribution of only bare earth. Just southeast of the center of the map and along the southeast side of Smoky Mountain, three separate seams of coal are being strip mined. With increasing demand for coal it is likely that these mines will progress along strike to the east along Dougherty Ridge and into Duncan Flats quadrangle. A map of the same quadrangle, produced in the same way from a Landsat tape of a year or more later could be used to monitor the progress of mining in this area.

TABULATION OF AREAL EXTENT OF CATEGORIES

Not only were the land-cover characteristics mapped, but also the area of each of the nine categories was measured (table 1). Computer printouts for the entire basin as well as for each of the 15 quadrangles were produced, showing area in terms of percentage of basin covered, acres, and square kilometres.

SUMMARY

Sediment produced by coal mining in New River basin discharges to Big South Fork Cumberland River a reach of which is being considered for development as a national recreation area. Land-cover information is needed presently to select small basins for study of hydrologic processes and eventually to transfer study results to other basins affected by coal strip mining. Digital computer processing of the spectral information in each pixel of 1.1 acres (4,500 m^2) in the Landsat tapes produced maps and tables of the areal extent of nine land-cover categories. These categories are water, rock, agricultural areas, evergreens, bare earth, uncategorized or unclassified areas and three categories of hardwood that correspond to different amounts of solar illumination. Although some categories include two or more land-cover types, they portray the predominant component named with accuracies ranging from about 5 to 15 percent. A map of the entire basin (1:62,500 scale) shows the general distribution of each category. Each of the 15 quadrangle maps (1:24,000 scale) shows the close relation between some categories and the topography. The drainage divide of a subbasin can be located on these maps, and the land cover can be determined accurately with as many as 2,900 data points in a 5 mi^2 (13 km^2) subbasin. A time sequence of maps of this type could be used to monitor the progress of mining activities. The land-cover information, both maps and tables, supplements other earth resources information normally obtained from topographic and geologic maps.

Table 1.--Area of land-cover categories in the New River basin by 7.5-minute quadrangle.

Quadrangle	Area in indicated quadrangle (acres)			
	Uncategorized	Water	Rock	Agriculture
Block	104	1	92	382
Duncan Flats	140	1	60	804
Fork Mountain	38	1	72	480
Gobey	0	0	2	66
Oneida South (Helenwood)	97	28	79	2767
Huntsville	29	1	76	4747
Jacksboro	9	0	2	2
Ketchen	0	0	0	1
Lake City	15	0	10	7
Norma	45	0	25	1486
Petros	11	0	0	38
Pioneer	11	0	45	519
Robbins	12	10	22	1120
Windrock	20	0	3	29
Winfield	1	1	6	124
In entire basin	534	44	494	12571

Table 1.--Area of land-cover categories in the New River basin by 7.5-minute quadrangle--(continued).

Area in indicated quadrangle (acres)				
Evergreens	Bare Earth	Hardwood I	Hardwood II	Hardwood III
1225	2831	7215	4246	16563
2491	3995	5948	4431	18815
886	2524	5563	5616	14555
586	15	978	533	2522
2486	1321	863	1808	13551
3392	783	2548	3868	22403
44	281	250	113	430
8	45	82	58	221
93	738	467	177	945
4511	1085	6283	4494	28011
311	68	613	374	2088
366	1307	2746	2063	6382
2747	227	1467	1311	11523
124	626	748	265	1483
117	35	494	285	1260
19385	15880	36263	29642	140753

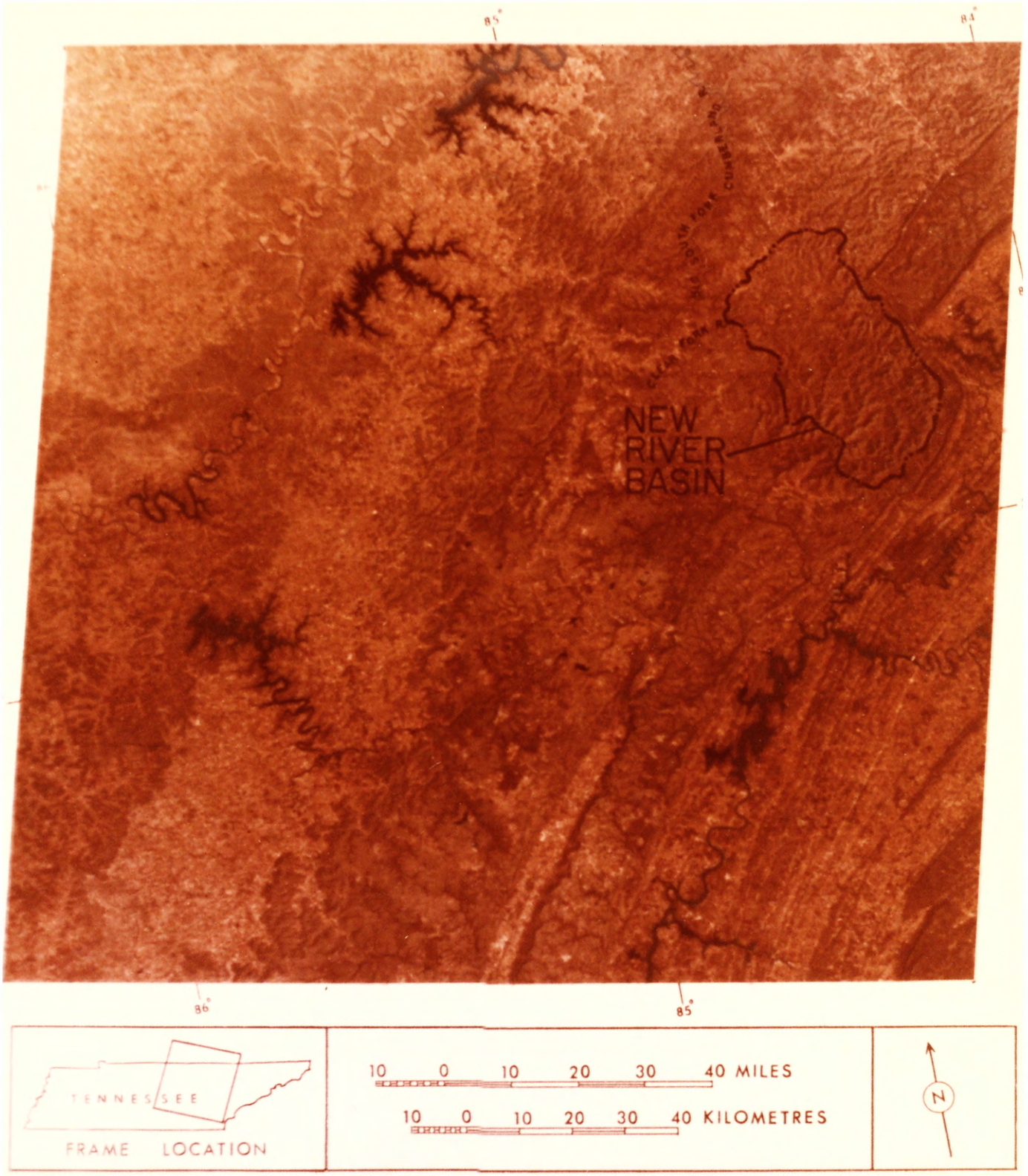

Figure 1.--Landsat-1 image 1265-15494 obtained April 14, 1973 showing location of New River basin along the eastern edge of the Cumberland Plateau. The many, small, blue-gray areas in the southeastern half of the basin are contour strip mines.

Figure 2.--Low-altitude, oblique aerial photograph of Stallion Mountain, along southern boundary of New River basin. Several levels of contour stripping constitute a good training area for processing tapes to discriminate bare earth category. Note mining equipment on bench in foreground. View to south. Winter, 1974-75.

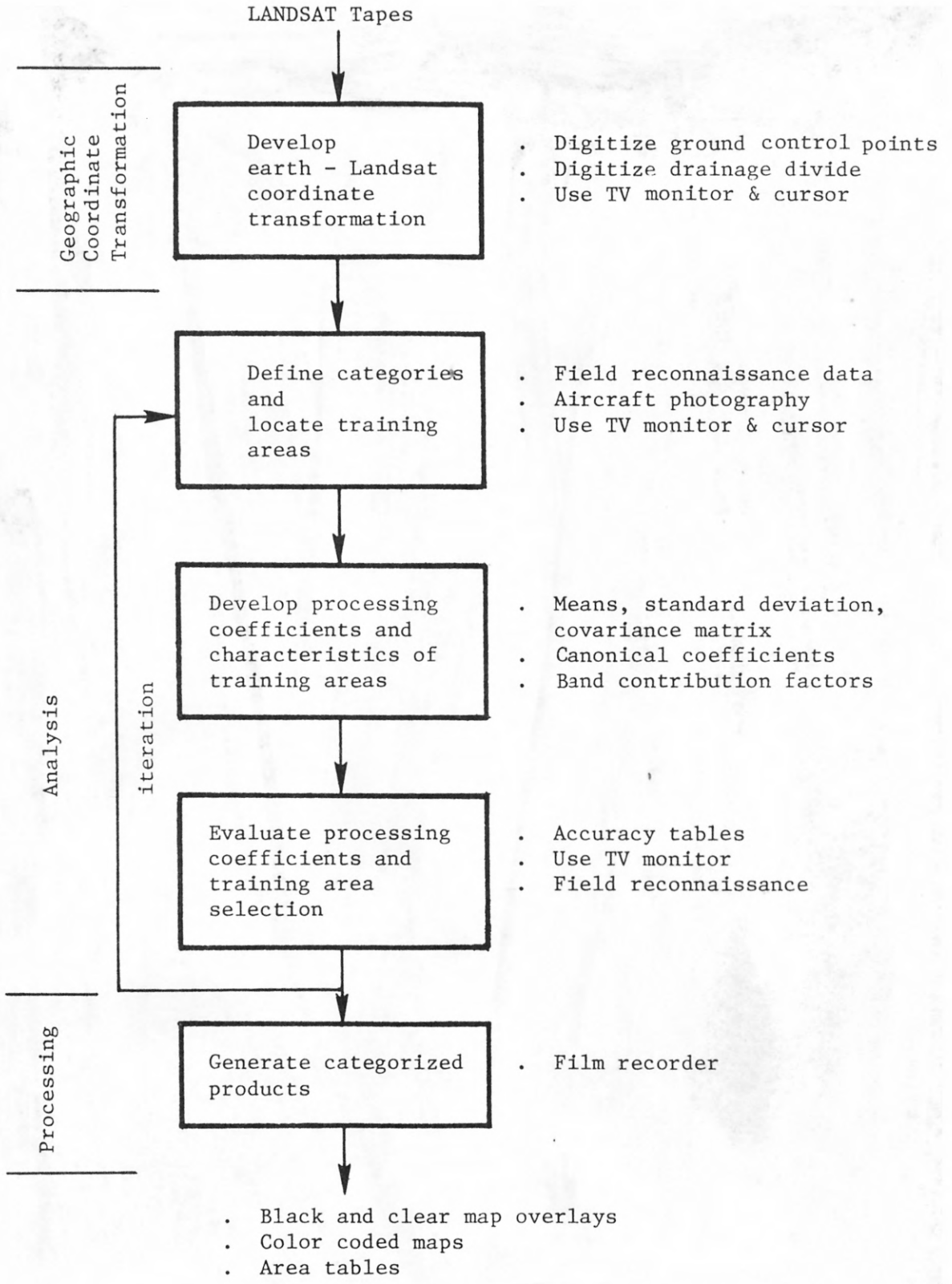

Figure 3.--Flow diagram for analysis and processing of Landsat tapes.

Figure 4.--Map of New River basin showing the distribution of the land-cover categories that characterize the drainage basin. The scale of the original map is 1:62,500.

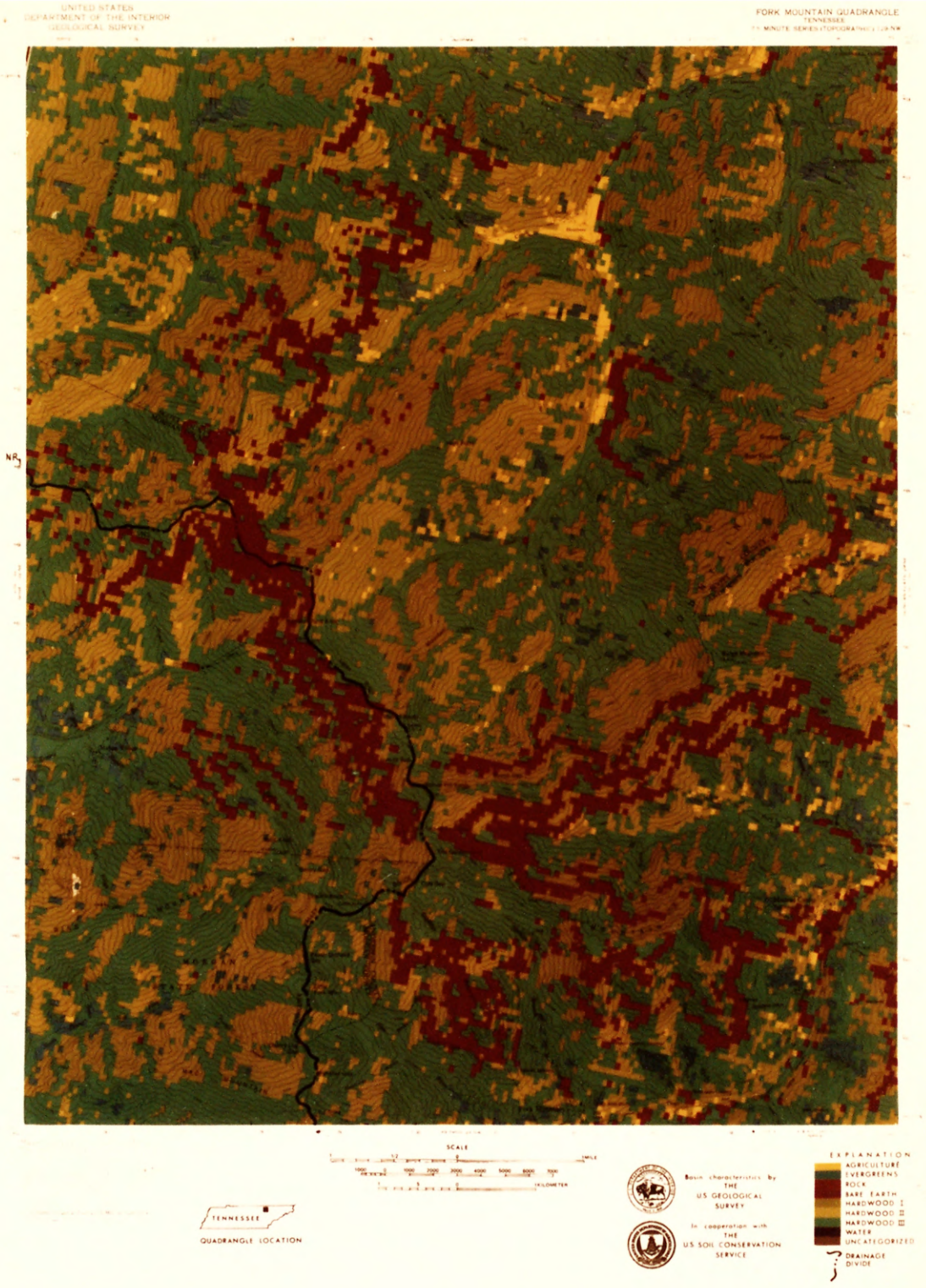

Figure 5.--Map of Fork Mountain 7.5-minute quadrangle showing the distribution of all land-cover categories. For quadrangle location, see index to topographic mapping, figure 4. The scale of the original map is 1:24,000.

Figure 6.--Map of Fork Mountain 7.5-minute quadrangle showing the distribution of bare earth category. For quadrangle location, see index to topographic mapping, figure 4. The scale of the original map is 1:24,000.

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