Reprinted from

Ninth International Symposium

Machine Processing of

Remotely Sensed Data

with special emphasis on

Natural Resources Evaluation

June 21-23, 1983

Proceedings

Purdue University
The Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907 USA

MAPPING PRIME TIMBERLAND USING LANDSAT AND GRIDDED SOIL DATA BASES

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ABSTRACT

Prime timberland maps and data bases were prepared for 12 counties in South Carolina and Georgia from Landsat imagery and USDA Soil Conservation Service gridded soil data bases. Information derived from the satellite imagery and ancillary data were combined to produce maps that effectively display the distribution and extent of forest cover by productivity class. The maps, printed at a scale of 1:100,000 and the data bases from which they were derived will be useful for environmental assessment and land management planning activities. Landsat images, acquired in 1973 and 1981, were independently classified to demonstrate the utility of satellite imagery in mapping changes in forest cover on prime timberlands.

The objective of the pilot test, conducted by Earth Resources Data Analysis Systems Inc. (ERDAS) under a contract from the USDA Forest Service, was to demonstrate the utility of available data sources and current technology for producing prime timberland maps on a cost effective basis. Image processing and geographic data base subsystems, implemented on mini and microcomputers, were used to perform the analysis.

I. INTRODUCTON

The Nation's forest lands are a unique natural resource, providing wood, recreation and wildlife habitat, as well as protecting soil and stabilizing water flow. Each year substantial acreages of forest land are converted to other uses. Continued conversion of the most productive prime timberlands impairs the nation's capacity to produce sufficient wood to meet domestic and export requirements. Land use allocation decisions, particularly those involving the conversion of prime agricultural and forest lands, are a major concern of the United States Department of Agriculture (USDA).[1] Decisions concerning land use arise from the need to accomodate necessary growth and development, avoid unwarranted conversion of forest and agricultural land, enhance production, and assure environmental quality.

The development, demonstration and implementation of objective procedures for mapping the nation's prime forest and agricultural lands are essential steps in ensuring their protection and consideration in land use planning and development. The USDA Soil Conservation Service (SCS) has defined a set of criteria based on limiting soil physical characteristics for mapping prime farmland and other important farmland classes. The SCS has mapped important farmland in more than 400 counties nationwide. In most states 200 meter (9.88 acre) gridded data bases were developed from existing soil surveys for the preparation of important farmland maps. The soil mapping units in the data bases were recoded according to the prime farmland criteria. The important farmland data layer was registered to 1:100,000 scale planometric base map prior to printing.

The pilot test was conducted to demonstrate an objective cost effective procedure for mapping prime timberlands using existing data. The same data bases used to produce the important farmland maps were used in this pilot test to derive the site productivity data for prime timberland maps. The timber productivity data layer was merged with a Landsat derived forest cover data layer to provide prime timberland maps displaying the relationship between site productivity and forest cover. These maps displays significantly more information for planning and decision making than could be displayed on single factor timber productivity or forest cover map.

II. STUDY AREA

Twelve counties in South Carolina and Georgia (fig. 1) were selected to demonstrate the utility of SCS soil data bases and Landsat imagery for preparing prime timberland maps.

The twelve counties, comprising 5,246,000 acres, are distributed between three physical divisions; the Blue Ridge, the Piedmont, and the Coastal Plain. Elevations in the subtropical lower coastal plain counties rarely exceed 100 feet, while elevations in the Blue Ridge Province of the northern counties range from 1400 to 3500 feet. The major forest types within the selected counties include loblolly-shortleaf pine, longleaf-slash pine, oak-pine, oak-hickory and oak-gum-cypress. The proportion of forest land in individual counties ranges from 38 to 83 percent. The topography, soil and forest cover in the selected counties cover a broad range of conditions representive of the South Atlantic coastal states.

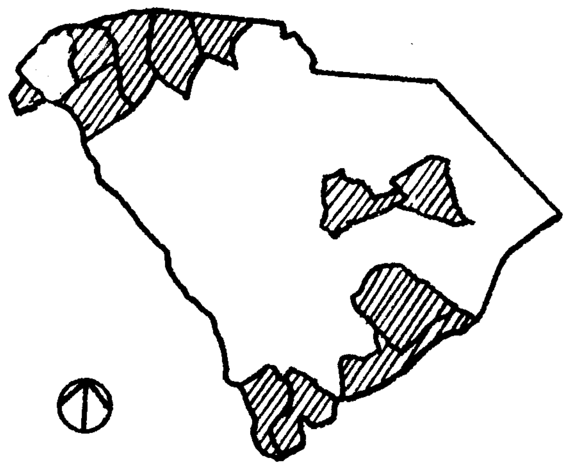

Figure 1. Pilot test counties South Carolina and Georgia.

III. FOREST COVER DATA LAYER

Portions of five Landsat Multispectral Scanner scenes were required to cover the pilot test counties. Scenes were selected to provide recent, cloud free, high quality coverage of the study area. The five scenes selected were acquired during four passes of Landsat 2 between March 26, and April 13, 1981. Landsat processing was performed to provide a forest cover data layer for each county (fig. 2).

EROS Digital Image Processing System (EDIPS) system corrected data tapes, resampled to the Hotine Obliques Mercator (HOM) projection, were acquired from the Earth Resources Observation System (EROS) Data Center. A subset of the original data encompassing each county was extracted from the original data for rectification to the Universal Transverse Mercator (UTM) coordinate system.

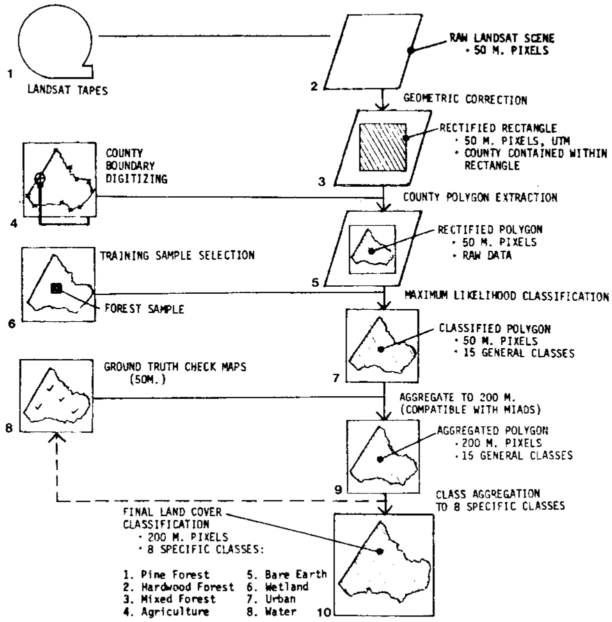

Figure 2. Forest cover data layer processing methodology.

A. IMAGE RECTIFICATION

Within each county block the image pixel coordinates and map coordinates (UTM) of approximately 15 recognizable control points were collected. These data were used to derive first order transformation matrices from pixel coordinates to the UTM data base coordinates. An iterative, least squares fitting procedure was used to derive final transformation matrices, with root mean square residual errors of one pixel or less. The county blocks were then rectified to 50 meter UTM coordinate pixels, using a nearest neighbor resampling rule. To extract the county from the rectified blocks, a file of UTM coordinates defining the boundary of each county was digitized from U.S. Geological Survey (USGS) 7.5' quadrangle maps. The areas defined by the county boundary files were extracted from each of the rectified blocks for further processing.

B. IMAGE CLASSIFICATION

A supervised maximum likelihood technique was used to classify each four channel county data set into between 15 and 20 land cover classes. Several training samples were identified for each land cover class to define its spectral characteristics. The cover classes sampled included forest, agriculture, bare earth, wetlands, urban and water. The training samples, each approximately 10 to 30 acres, were identified on recent aerial photographs and interactively delineated on the processing systems image display. The data for each county was then processed, using the appropriate training samples and the maximum likelihood classifier. The data were reprocessed if sigicant misclassification was detected.

C. ACCURACY ASSESSMENT

Using the overlay capability of the image processing system, each of the individual cover classes was overlaid on the raw data and compared with the aerial photographs and USGS 7.5' quadrangle maps to check accuracy of classification. To further verify classification accuracy, check maps at two scales were prepared using a dot matrix printer. The 15-20 classes in the original classifications were displayed in one of the three summary classes; forest, non-forest and water, on the check maps. Check maps at a scale of 1:100,000 scale were used to evaluate overall classification accuracy insuring that no major classes were omitted or incorrectly assigned. Check maps at a scale of 1:24,000 were generated for selected 7.5' quadrangles in each county. In the counties where recent photography was at a scale of 1:24,000, the check map, 7.5' quadrangle and aerial photography were overlaid and registered on a light table. The cultural features on the USGS maps facilitated registration of the aerial photographs and image classification check maps. Photo interpretation procedures were used to evaluate the classification for each of the selected quadrangle maps. Contingency tables were generated for each county classification to determine the percentage of the training sample pixels classified into the correct summary land cover class.

IV. FOREST PRODUCTIVITY DATA LAYER

USDA Soil Conservation Service County Soil Surveys served as the basis for developing the timber productivity data layer for the prime timberland maps. The soil surveys for the pilot test counties had previously been coded into a 200 meter (9.88 acres) Map Information Assembly and Display System (MIADS)[2] data bases by the USDA Soil Conservation Service for preparation of important farmland maps. Computer compatible tapes of the MIADS data bases were provided by the SCS contractor Compuroute Inc.

The definition of prime timberland used in this study is consistent with the USDA Statement on Land Use policy.[1] Prime timberland is defined as land that has soil capable of growing wood at a rate of 85 cubic feet or more per acre per year at culmination of mean annual increment (site class 3 or better) in natural stands, not in urban or built-up land uses or water.

To delineate the most productive sites in the study area, prime timberland was divided into two classes. The first class consisted of stands capable of growing wood at a rate in excess of 120 cubic feet per acre per year (site classes 1 and 2). The second class includes land capable of growing wood at a rate between 85 and 120 cubic feet per acre per year (Site Class 3).

A. ASSIGNMENT OF PRODUCTIVITY CLASSES

Site index, height at age 50, was used as a basis for defining the productivity of the soil mapping units in each county. The USDA Forest Service site class site index curves[3] were used to determine the minimum qualifying site index of the two prime timberland classes for the principal timber producing species.

Individual county surveys often included as many as 150 soil mapping units. These classes represented combinations of soil series, slope and erosion classes. Each soil mapping unit was assigned to a timber productivity class on the basis of the site index for the most desirable species listed in the SCS county soil surveys. A soil scientist participated in the process of assigning productivity classes to soil mapping units.

B. DATA BASE REFORMATTING

The MIADS data bases consisted of a header section, an important farmlands recode table, and a series of data base records. Each data base record contained the two character soil map unit codes for 36 data base cells and an identification field.

Preparation of the prime timberland maps required reformatting the MIADS data bases into four bit, binary coded, raster data bases and recoding of soil mapping units into the approropriate timber productivity classes (fig. 3).

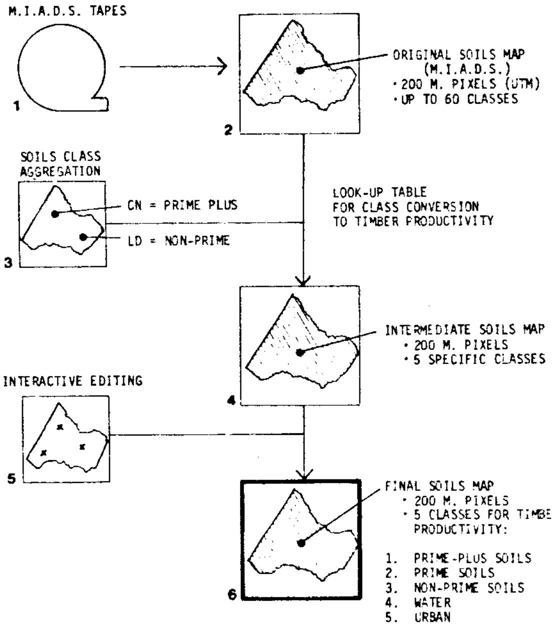

Figure 3. Forest productivity data layer processing methodology.

A data reformatting program was written to restructure the strips of the MIADS data base into a binary coded raster data base compatible with the ERDAS 400 analysis system. During the reformatting process, the MIADS soil mapping unit code of each cell was recoded through a lookup table to the appropriate productivity class.

Where necessary, scaled dot matrix printer check maps were prepared to evaluate missing or miscoded soil mapping units. The timber productivity data layer consisted of five classes: soils capable of producing greater than 120 cubic feet of wood per acre per year; soils capable of producing between 80 and 120 cubic feet of wood per acre per year; soils capable of producing less than 80 cubic feet of wood per acre per year; water, and urban.

V. INTEGRATION OF FOREST COVER AND TIMBER PRODUCTIVITY DATA LAYERS

A. AGGREGATING THE FOREST COVER DATA LAYER

Combining the forest cover and timber productivity data layers requires that the cells in both data layers have the same dimensions. The soil data base from which the timber productivity data layer was derived, was gridded to a 200 meter cell size. Unacceptable spectral averaging would have resulted if the Landsat data had been resampled to a 200 meter cell size before classification. To resolve the difference in cell dimension between the two data layers, the final eight class forest cover classification was aggregated to a 200 meter cell size. The sixteen 50 meter cells, comprising each 200 meter cell, were spatially aggregated on the basis of the predominant cover class (fig. 4). This produced a new forest cover data layer that could be directly combined with the forest productivity data layer.

B. COMBINING FOREST COVER AND PRODUCTIVITY DATA LAYERS

Combining the forest cover and forest productivity data layers was the final step in preparing the prime timberlands data bases. For each county data base the eight class forest cover data layer was recoded into two summary classes, forest and non-forest. The forest cover and productivity data layers were combined using the data base matrix operation as shown in figure 5. The five classes in the productivity data layer formed the columns of the matrix and the two summary classes of the forest cover data layer formed the rows. The intersections of the row and column values defined the eight final prime timberland data classes.

C. MAP PREPARATION

The final prime timberland data base layer was displayed on the ERDAS 400 color monitor to evaluate the pictorial impact of alternative color patterns. Once a color scheme was selected, a 4X5 inch color positive of the prime timberland data base for each county was generated on a Dicomed film recorder. Enlarged color separations, scaled to the 1:100,000 planometric base map, were prepared for each county. The color separates were pin-registered to the base map for preparation of proofs and final printing plates. Three hundred maps were printed for each of the 12 counties in the pilot test. (fig. 6)

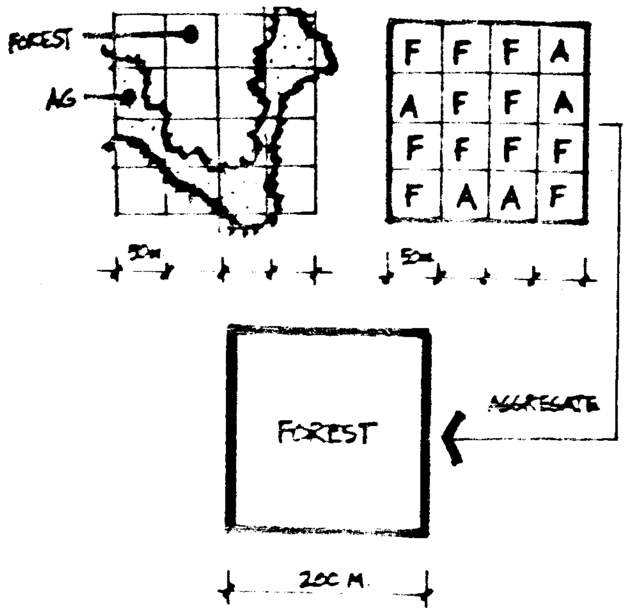

Figure 4. Spatial aggregation of 50 meter forest cover cells to a 200 meter cell size.

M.I.A.D.S. FOREST PRODUCTIVITY

LANDSAT FOREST COVER		PRIME PLUS 120+	PRIME 80-120	NON-PRIME <80	WATER	URBAN
	FORESTED	CLASS 1	CLASS 2	CLASS 5	CLASS 7	CLASS 8
	NON-FORESTED	CLASS 3	CLASS 4	CLASS 6	CLASS 7	CLASS 8

Figure 5. Matrix of forest cover and productivity data layers.

VI. PRIME TIMBERLAND CHANGE MAPPING

Landsat data acquired on March 10, 1973, was selected for processing in conjunction with the previously classified scene acquired on April 13, 1981, to demonstrate the utility of satellite imagery for mapping change in prime timberland. A subset of the March 1973 scene encompassing Beaufort County, South Carolina, was rectified and resampled to 50 meter UTM referenced pixels. Data within the county boundary was extracted, utilizing the previously developed county boundary coordinate file. The 1973 data was then independently classified utilizing a maximum likelihood decision rule as previously described.

The cover classes in the 1973 and 1981 classifications were then recoded to forest and nonforest classes. A data base matrix operation (fig. 7) was performed to derive a change data layer consisting of three classes; no change, change from non-forest to forest, and change from forest to non-forest.

		DATE 1: APRIL 1973 CLASSIFICATION	
		FORESTED	NON-FORESTED
DATE 2 MARCH 1981 CLASSIFI-CATION	FORESTED	CLASS 1	CLASS 2
	NON-FORESTED	CLASS 3	CLASS 1

Figure 7. Forest change matrix.

The 50 meter forest change data layer was aggregated to the 200 meter cell size of the forest productivity data layer. This aggregation, on the basis of the plurality of the sixteen 50 meter cells within a 200 meter cell, had the effect of deleting single cells or small groups of cells in the change classes. These small groups of change cells can result from slight misregistration of the two data sets or errors in classification. A second matrix operation was performed, utilizing the aggregated forest change and forest productivity data layers, to derive a final prime timberland forest cover change data layer.

VII SUMMARY.

A procedure for mapping prime timberland, based on a soil data base derived forest productivity data layer and a Landsat MSS derived forest cover data layer, was implemented and demonstrated for 12 pilot test counties in South Carolina and Georgia. The techniques for preparing the productivity and forest cover data layers are straightforward, objective and robust. These techniques can be applied outside the Southeast by substituting appropriate site class site index curves. Use of the procedure is limited only by the availability of detailed soil surveys with estimates of the site index for each mapping unit. County soil data bases suitable for developing the timber productivity data layer are available for the majority of the more than 400 counties for which the SCS has prepared important farmland maps. The cost of the data base and map preparation, including printing 300 color maps for each of the 12 pilot test counties, was approximately 1.2 cents per acre.

The prime timberlands mapping procedure demonstrated in this pilot test can be applied by any organization with access to image processing and geographic data base systems. In the Southeast approximately one half of the states, for example, have access to image processing systems either through a state agency or an educational institution.

The USDA Forest Service has the capability to perform the prime timberland mapping procedure demonstrated in this project. The Resource Evaluation and Monitoring Integrated Data Analysis System (REMIDAS), implemented by the Georgia Institute of Technology Engineering Experiment Station for the USDA Forest Service under a recently completed cooperative agreement,[4] includes the necessary image processing and geographic data base processing software. Special purpose software, developed during the project for MIADS data base reformatting and Landsat spatial aggregation, have been transferred to the USDA Forest Service.

Data processing for the pilot test was performed on a Data General Eclipse S230 minicomputer based analysis system and on a Z80 microcomputer based ERDAS 400 analysis system. Satellite imagery rectification and classification and MIADS data base reformatting were performed on the Eclipse S230 minicomputer based analysis system. The remainder of the processing, including coordinate digitizing, training field selection, accuracy assessment and data base manipulation, were performed on the ERDAS 400 microcomputer based analysis system. This pilot project demonstrates the utility of low cost microcomputer based analysis systems for operational resource management applications.

VIII. REFERENCES

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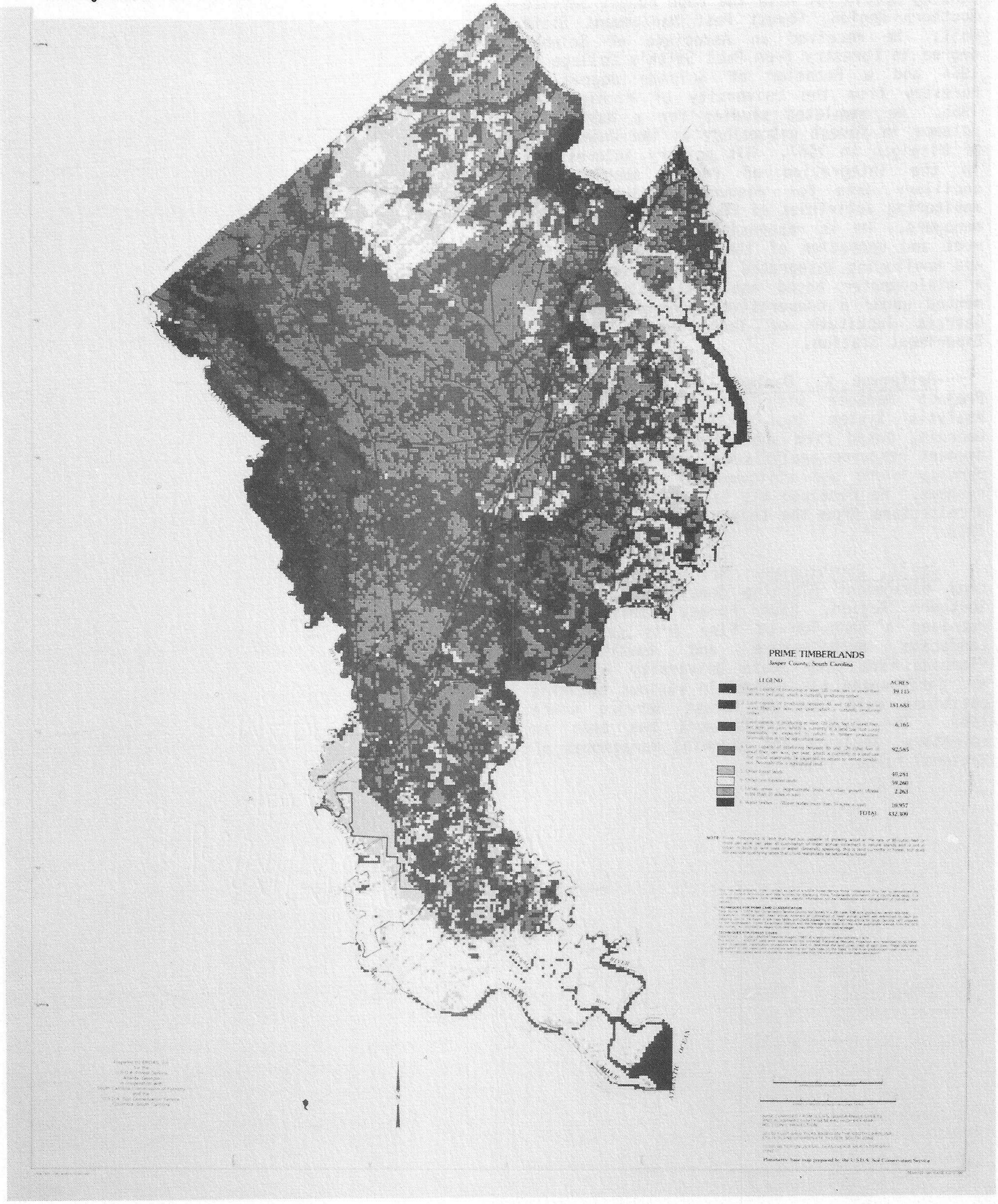
USDA FOREST SERVICE PRIME TIMBERLANDS JASPER COUNTY SOUTH CAROLINA

Figure 6 Prime timberlands map Jasper County South Carolina.



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