INTEGRATION OF INFORMATION ON VEGETATION DERIVED FROM LANDSAT THEMATIC MAPPER DATA INTO A NATIONAL FOREST GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

Based on Landsat Thematic Mapper (TM)* data acquired in August 1990, a geographic information system (GIS) forest vegetation layer was developed for the Catahoula Ranger District of the Kisatchie National Forest, Louisiana. Supervised classification techniques were used to identify open land and regeneration, pine, hardwood, and mixed pine/hardwood forest classes. Low- and high-crown-density pine subclasses were also included in the final classification. Ground verification data for classification training and assessment were based on GIS stand data and aerial photography. Integration of the classification data with GIS has allowed resource analysts to use this information in stand management planning.

KEY WORDS: Forest Management, Image Analysis, Geographic Information System, Landsat Classification, Landsat Thematic Mapper, National Forest.

BACKGROUND

Remote sensing by satellite has played a significant role in forest mapping, especially for Western lands (Bain 1988; Born 1988; Walsh 1980; Woodcock et al. 1990). Use of this technology has been less widespread in the Southern United States --an area with many diverse timber species. Unlike mountainous areas of Western States, in the South forest classifications from satellite data cannot be easily modified based on ecological gradients in elevation or aspect (Frank 1988; Cibula and Nyquist 1987; Strahler et al. 1978). Other ancillary information, such as vegetation or detailed soils maps, is often lacking. Therefore, data analysis procedures rely heavily on the spectral characteristics of forests to define meaningful cover classes for forest management.

Detailed forest types may not be discernible in satellite data of the Southern United States. However, simple forest types (e.g., pine, hardwood) can be mapped with reasonable accuracy with Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data (Evans and Hill 1990). Such general forest classifications from Landsat, in combination with geographic information system (GIS) data, can provide information needed for management decisions on National Forest lands.

This project demonstrated the integration of Landsat TM classifications into a GIS of the Kisatchie National Forest to provide information for stand- and compartment-level forest management. TM data were selected because they provide coverage of broad areas with a resolution (30 m) suitable for use with GIS layers at the ranger-district level. Procedures were designed to be easily repeatable for periodic updates of conditions on National Forest lands. Details of the technical aspects of data analysis are given by Evans et al. (in press).

METHODS

The Kisatchie National Forest consists of six ranger districts in Louisiana. A GIS of the Catahoula Ranger District was first developed and delivered in 1989. Current information in this GIS includes data on timber stands, special use areas, sensitive species, superior trees, wildlife key areas, roads, streams, soils, and cultural resources. The GIS, based on ARC/INFO software,

*Mention of equipment, products, or company names is solely for information purposes and does not constitute official endorsement by the USDA Forest Service.

was loaded into the computer network at the Southern Forest Experiment Station, Forest Inventory and Analysis unit (SOFIA), for processing and analysis.

Landsat TM data imaged on August 11, 1990, were acquired for the study. These data were approximately one year older than the original GIS database used in the project. Thus, TM classifications and the original GIS could be compared to demonstrate GIS updates.

The TM data were georegistered to the Universal Transverse Mercator projection and then reprojected into State plane coordinates for use with the GIS. The red, near-infrared (IR), and two mid-IR channels were used for the classification.

Landsat Data Analysis Procedures

The TM data were subjected to supervised classification. Signature training fields and holdout (test) polygons were selected interactively within GIS stand boundaries overlayed on the image data. Key attributes such as stand forest type and density in the GIS tabular data were used to determine the stands for sampling. The data for each spectral band in the training polygons were used to develop statistical definitions (signatures) of six cover classes: (1) open/harvest areas, (2) pine regeneration, (3) pine, (4) mixed forest, (5) hardwoods, and (6) water. Color, 1:24,000-scale and color-IR, 1:58,000-scale aerial photography was used to verify the characteristics of the training and test polygons. Signatures for each class were merged to form final statistical definitions for the cover classes. The maximum likelihood algorithm in the Earth Resources Data Analysis System (ERDAS) image-processing software package was used to classify the data and produce a thematic map of the six classes.

Additional signature training and a second classification were used to identify low- and high-crown-density pine sub-classes within the pine type. The results from the two classifications were combined into a final map of the ranger district. A boundary mask was used to reduce the area of the final classification to a forest cover map of the National Forest.

The distribution of pixels in each of the holdout polygons was determined. Although several classes could occur in any holdout area, a majority approach was used to determine whether the classification agreed with the holdout areas. The forest cover class of each holdout area was determined by the following criteria: pine, > 69 percent pine pixels; hardwood, > 69 percent hardwood pixels; and mixed, 31 to 69 percent pine or hardwood. A more detailed explanation and the results of this process are given by Evans et al. (in press).

GIS Data Integration

The final classification was converted into an ARC/INFO coverage (GIS layer). The classification and stand data were recombined in order to analyze the classification at the stand level. A representative set of standard inquiries are being developed to demonstrate how the GIS and Landsat classification can be used to make decisions about the district. Adjustment of stand boundaries based on the classification is also being investigated.

RESULTS AND DISCUSSION

All phases of the classification process were easily implemented and quickly completed. The agreement between the holdout areas and basic forest cover classes was 86 percent. The average agreement for all classes was 84 percent and for the two pine density classes, 79 percent.

The procedures used in this study are considered both efficient and repeatable. Future classifications can be effectively compared with past work to detect changes and analyze trends. Stands that are not expected to change significantly between two successive years should be used for classification training (to provide for consistency in training procedures). The spectral characteristics of the stands may change, however, because of uncontrollable differences in illumination conditions.

Discrepancies between classifications or between classification and field-derived stand data may emphasize changes in the composition or condition of forest stands. Stands labelled as pine regeneration on the ground and misclassified as hardwoods may need release work to control competition from hardwood and herbaceous vegetation. Areas associated with various forms of timber damage (insects, flooding, wind) may classify as high-density pine in a particular image year and low-density pine or partly open forest cover in the next.

Maps (electrostatic printer plots) of the classifications as well as areas of interest where National Forest personnel are evaluating stand management plans (prescriptions) were produced for the ranger district. They are also being developed to illustrate the agreement of the classification with the stand attributes in the GIS.

Plots of the classifications and stand agreement tests are providing National Forest personnel with graphic indications of stands that may need to be assessed for thinning, hardwood control, or extended regeneration efforts. A recent example of how the classification was used follows.

A field forester was reexamining stands where pine timber was to be thinned (selectively cut for sale and stand improvement). However, some of the previously identified areas did not actually have enough timber volume to cut (inoperable). The Landsat classification revealed that the inoperable areas were identified as low-density pine. Other areas that had not been included in the original thinning plans, but could have been, were identified on the classification as high-density pine. This example illustrates how the Landsat classification can provide useful information for planning timber management and harvests.

Combining classification and GIS data provides a wealth of information that can be used for complex management decisions. Stand age and condition in the GIS can be used with the density classes from Landsat to determine where harvesting, stand improvement, and other timber management options are warranted. Stand boundaries can be easily redefined based on harvest patterns and logical grouping of similar timber types and stand densities that may not have been previously identified.

Nontimber management plans can be developed by using the geographic analysis capabilities of GIS. Landsat classifications provide basic information on vegetation; in combination with other GIS data, this can be used for assessment of wildlife habitats, protection of endangered species, and management of riparian zones.

CONCLUSIONS

Documentation requirements for timber sales and prescriptions have reduced the total time foresters can spend in the field. Basic information on forest vegetation can be efficiently extracted from Landsat TM data and incorporated into GIS to use in forest management decisions. As demonstrated by this project, Landsat classifications can be good sources of information to supplement field data on timber stand conditions.

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