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PROBLEMS RELATED TO THE USE OF REMOTE SENSING FOR INVENTORY AND MAPPING OF LOWER COASTAL PLAIN FORESTS

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Studies involving Landsat MSS imagery of the southeastern United States have indicated that its primary usefulness would be of mapping for forest versus non-forest features (1,2,3,4). Best results have been obtained using imagery taken during spring or using combinations of two seasons (1,2,3,4). Color infrared aerial photographs are similar to the Landsat MSS in spectral sensitivity (5,6), but provide more detail of importance to forest managers than satellite imagery, especially if taken at medium scales (1/10,000 to 1/20,000) (7,8,9).

Aerial photography is important and is used commonly for mapping forest stands, estimating areas, and planning silvicultural operations (9). Ground observations, although costly, are recognized as the most important source of information used in forestry operations. Neverthless, satellite imagery has several characteristics that might be used beneficially in forest inventory applications. Among these are repetitive coverage and wide area coverage, the capability for machine assisted analyses, and multispectral properties (5,6).

This study was designed so that the use of satellite imagery would help reduce the area covered by aerial photographs. Next, the use of aerial photographs would in turn reduce the number of ground samples needed for forest inventory. The reliability of land cover classification from Landsat data for the hydrophytic forest types was not acceptable for use in expanding forest type volume estimates to the total area basis. Also, there were several other problems that made it difficult to incorporate satellite imagery into a system of forest inventory. The purpose of this paper is to discuss the major problems influencing the usefulness of satellite imagery and other remote sensing products for inventory of Lower Coastal Plain forests.

I. STUDY AREA

The 731,239-acre study area was located in the Lower Coastal Plain in South Carolina. There is little topographic variation in this region, but minor changes in elevation are often accompanied by major differences in soil types and drainage characteristics. In addition to a great natural diversity and occasional natural disturbances, intensive silvicultural and other man-related activities have marked effects on the vegetative composition of forest lands. Forest lands cover more than seventy percent of the area, and forest products rank second to tourism as the major source of income.

II. EXPERIMENTAL DESIGN

Satellite imagery taken January 5, 1979, was classified into a digitally coded land cover map using supervised techniques in cooperation with the USDA Forest Service (Southeastern Area State and Private Forestry) and the Georgia Institute of Technology (Engineering Experiment Station). Classification involved the use of band 5, band 7, band 5/7 ratios, and band 6/7 ratios based on training samples located with the help of aerial photographs. Five east-west flight strips of aerial photographs, systematically located and exposed on November 1, 1979, were delineated into forest and other land cover types. The delineated area represented about 12.4 percent of the total study area. One hundred seventy-eight ground samples, collected during the summer of 1979, were used to supply timber volume estimates and to help evaluate classifications of vegetation derived from remote sensing.

Aerial photographs were assigned an important dual role in the inventory and experimental design. First, estimated areas of pine, deciduous, mixed, cypress-tupelo (forested wetland), and disturbed (harvested) forest lands were compared between each photographic flight strip and a rough equivalent strip extracted from the satellite data. Second, photographic sample plots were used with ground samples and double sampling with regression to provide more precise timber volume estimates (11).

III. RESULTS AND DISCUSSION

Based on aerial photographs and ground samples, forest lands in the study area were estimated to contain 1,170 cubic feet of merchantable timber volume per acre (Table 1). Photographs were used to estimate that 69.8 percent of the area was forested. The total volume estimate was 597.2 million cubic feet.

The USDA Forest Service prepared a special inventory of the study area based on the 1978 Renewable Resources Evaluation (11). The Forest Service estimated that 63.6 percent of the study area was forested with an average volume of 1,338 per acre. The total volume estimated was 619.7 cubic feet, or about 4 percent greater than the estimate obtained in our study.

Table 1. Results of a forest inventory based on aerial photographs and ground samples for the Lower Coastal Plain study area in South Carolina, 1979.

Forest Cover Type	Percent of Total Area1/	Volume per Acre2/	Sampling Error (percent)	Total Volume (10^3 cu. ft.)
Pine	27.3	988	8.9	197,233
Hardwood	8.6	306	13.5	19,243
Mixed	27.7	1,021	9.0	169,477
Cypress-Tupelo	6.6	4,378	7.1	211,290
Harvested	3.7	0	-	-
Non-Commercial	0.9	0	-	-
TOTAL	69.8	1,1703/	-	597,243
FOREST SERVICE	63.6	1,338		619,690

1/ The study area contains 731,239 acres.

2/ Merchantable volume in cubic feet based on double sampling with regression from aerial photograph and ground samples.

3/ Based on combined totals, for total forested area.

Because of the differences in defining forest types, estimates of area and volume could not be compared for the individual forest types. In general, however, considerably more area was delineated as pine forest and hardwood forest, using aerial photographs than would have occurred based on ground observations. This difference was due to the minimum area mapped from the photographs (10 acres) being considerably greater than the area observed from the sample on the ground (less than one acre). The wider view afforded by the aerial photography would be advantageous in many forestry applications because timber stands are normally delineated as units of more than 10 acres.

The original plan to use satellite imagery for expanding the per acre volume estimates of individual forest types (Table 1) to a total area basis was not fully successful. The overall quality of the Landsat derived type map was questionable for several categories, and the map was time-consuming and costly to produce. We were comfortable and confident in the inventory when based on aerial photographs and ground samples. The same confidence was not apparent to the authors when satellite imagery was included as a final step in the inventory procedure.

The greatest intial problem was in obtaining a satellite scene without cloud cover for the time period of the study. The only imagery meeting these specifications was taken in winter. Poor scene contrast and sixth-line banding were evident and affected the quality of classification results. In addition, there was extensive flooding throughout the study area on the date of imagery.

Another problem was the development of a vegetative classification system that was consistent between ground observations, photo-interpretation, and the digitally classified satellite imagery. A major reason for these problems was the difference in the resolution or minimum mapping area of the three methods. Also, all three methods (including satellite imagery) were subjective because they involved human interpreters and computer software written by humans. Although no single source was considered to give accurate vegetative classifications in every case, classifications from ground samples and aerial photographs were in agreement much more frequently than classifications from satellite imagery and either of the other two sources.

Obvious misclassifications were apparent in the satellite image data when compared to strips of aerial photography. The most serious errors were in the classification of non-forest wetlands (tidal marshes) as cypress-tupelo (forested wetland) and the classification of scattered agricultural and harvested forest areas as non-forest wetlands. These problems were attributed to low scene contrast and extensive flooding on the date of imagery. Oddly enough, area percentage estimates for the five forest types were very similar for both winter satellite imagery and fall color infrared photographs when the five flight strips were combined.

While pinpointing ground sample locations on aerial photographs was not easy, locating samples on the satellite imagery was much more difficult. These problems were encountered despite considerable efforts and computer time spent in modeling image scene coordinates against measured map coordinates. Difficulty in locating points on the imagery was quite variable, and was easiest when samples fell in close proximity to bodies of water or sharp contrasts in land cover. In many cases, areas interpreted as homogeneous from the ground or photographs were not mapped as homogeneous features from the satellite imagery.

Quantifying the accuracy of the inventory results was also difficult. A major problem was that definitions of categories mapped from remote sensing differed from categories mapped or sampled in previous inventories. Nevertheless, use of double sampling with regression within each of the five forest type strata resulted in an estimate of the average cubic foot volume per acre that was within 4 percent of the 1978 USDA Forest Service estimates for the study area (11).

The detail and accuracy of information supplied from the satellite data was far below that provided from ground samples and aerial photographs. Money spent on data processing of satellite imagery could have been used to increase coverage with ground samples and photographs significantly. Effective use of satellite imagery would require improved image quality (resolution, radiometric properties, and optimum seasons) and more efficient equipment and methods of data processing.

IV. SUMMARY AND CONCLUSIONS

A forest inventory procedure using satellite imagery, medium-scale color infrared aerial photographs, and ground samples was implemented for a large study area in the Lower Coastal Plain in South Carolina. Problems affecting future decisions to use remote sensing tools were encountered. The problems were most serious with regard to the use of satellite imagery, but could apply to any type of remote sensing. Future decisions to use remote sensing in forest inventory work must recognize the following as potential problems:

1) It may be difficult to obtain remote sensing of acceptable quality within the desired time period.

2) Specialized equipment and trained personnel must be available and affordable.

3) Vegetative classifications provided using remote sensing will be subject to certain constraints and might not be compatible with observations from the ground or results using other dates, types, or classification methods of remote sensing.

4) Usefulness of remote sensing can be hampered by costs and difficulty in locating specific points of interest.

5) Verifying the accuracy of inventory results based on remote sensing is complicated due to mapping resolution properties and other differences when compared to conventional inventory methods.

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