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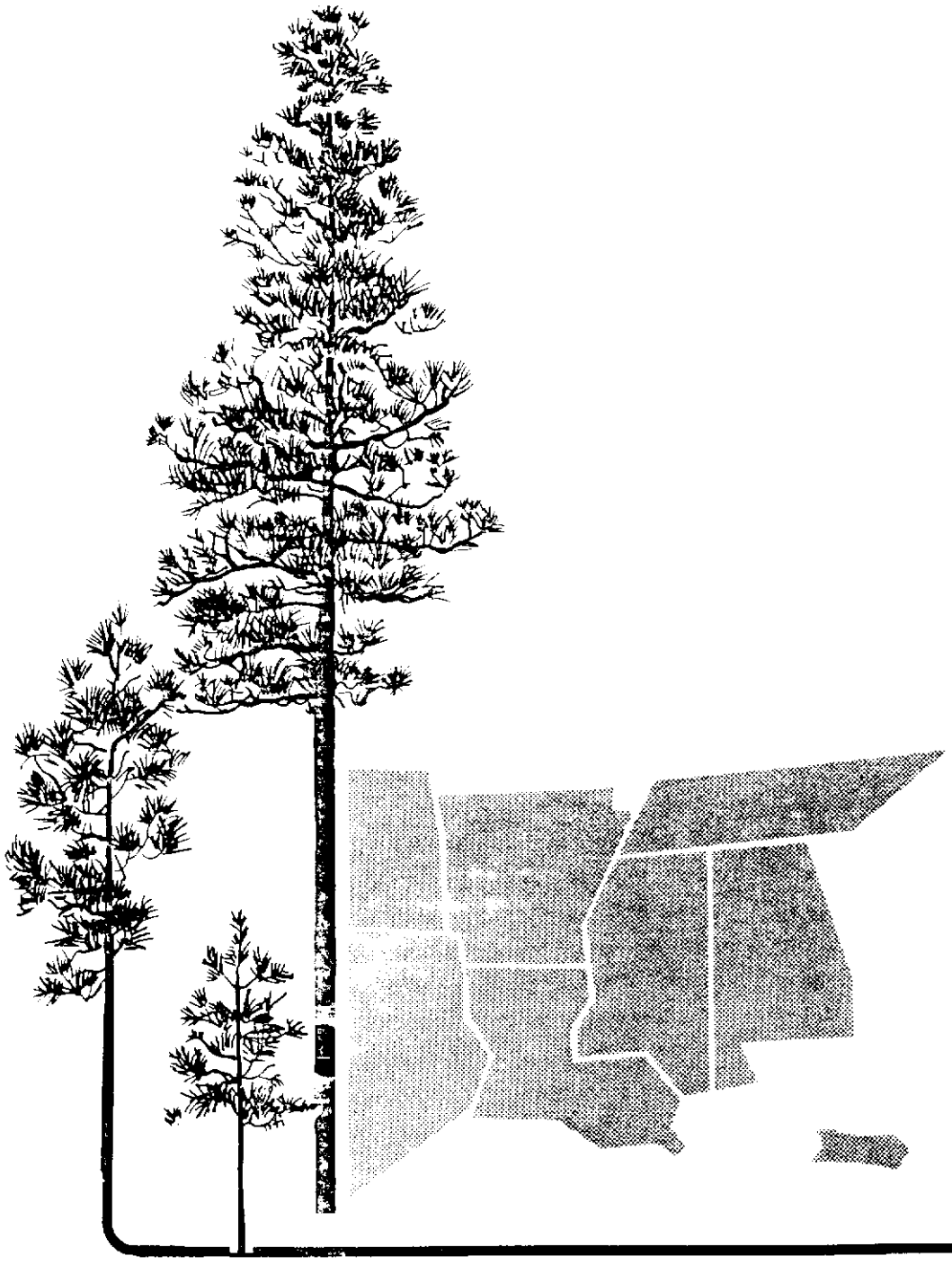

Southern Forest Experiment Station

THE USE OF REMOTE SENSING FOR UPDATING EXTENSIVE FOREST INVENTORIES

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ABSTRACT

The Forest Inventory and Analysis unit of the USDA Forest Service Southern Forest Experiment Station (SO-FIA) has the research task of devising an inventory updating system that can be used to provide reliable estimates of forest area, volume, growth, and removals at the State level. These updated inventories must be accomplished within current budgetary restraints. Remote sensing is expected to provide important data elements for the updating system. Advanced Very High Resolution Radiometer satellite imagery, combined in a multi-stage design with more detailed data such as Landsat TM, will be used to produce estimates of forest area. SO-FIA is also evaluating the use of satellite imagery to obtain data on forest type, stand size, area change, and detection of harvest and regeneration activities. The linking of satellite data with geographic information systems technology is expected to enhance the usefulness of remotely sensed data in inventorying large areas.

INTRODUCTION

The Forest Inventory and Analysis unit of the USDA Forest Service Southern Forest Experiment Station (SO-FIA) is responsible for inventorying all forest land in seven Midsouth States and Puerto Rico. This responsibility extends across all ownerships. The latest estimate of the forest area in the Midsouth States is 101 million acres; 99 million acres of this total is timberland, or forest land capable of producing at least 20 cubic feet of timber per acre per year and not reserved from timber harvesting. We are currently inventorying Midsouth States on about a 7- to 8-year cycle. Due mainly to the dynamics of the timber industry in the South, there is great interest in SO-FIA data.

The survey is designed to provide reliable information at the State level. For area and timber volume, sampling error (which is one standard deviation) must not exceed 1 percent per million acres and 5 percent per billion cubic feet of timber. Each State is divided into several units or regions in order to facilitate the survey work and reporting of results. It should be emphasized that SO-FIA data is not accurate at the county level; typical sampling error for total volume is 10-25 percent for individual counties.

As in any survey, there is a compromise between accuracy and timeliness. Any survey cycle shorter than the present one, given current funding, would not yield acceptable results. Since funding is not likely to increase, any increase in survey frequency or accuracy must be achieved by the application of new technology.

The application of new technology, including remote sensing and data management, to improve the frequency, accuracy, and utility of State inventories is one of only two research problems in the current research work unit description for the SO-FIA unit. To conduct this research, the unit has acquired computer hardware and software to process remotely sensed data and geographic information. The combination of satellite imagery processing and geographic information systems (GIS) technologies provides significant opportunities to increase the frequency, accuracy, and utility of State-level inventories.

Our use and proposed development of remote sensing technologies for application to the extensive surveys conducted by the SO-FIA unit are described in this paper.

FIA PROCEDURES

A two-phase sampling procedure is used in conducting State inventories. Forest area is estimated by classifying aerial photographs on a forest-nonforest basis. This classification is accomplished for plots representing approximately 230 acres. Ground checks of these classifications are then done on plots representing about 3,840 acres. These ground checks are necessary because the photographs used may be several years old.

The second phase of the survey entails the measurement of trees on forested plots located at the intersections of a rectangular grid of lines spaced 3 miles apart. Expansion factors are computed for individual counties based on the total forest area and the total number of forest plots. Given the grid spacing, the average expansion factor for these on-the-ground measurements is 5,760 acres. A satellite system of 10 points is used on each plot, covering a total area of approximately 1 acre. Merchantable trees--those at least 5.0 inches in diameter at breast height--are selected using a prism with a basal area factor of 37.5. A plot with a 7.1-foot radius is used to sample smaller trees.

A principal advantage of surveys conducted by the forest inventory and analysis unit is the permanent location of the primary plots. This facilitates trend analysis, which is very important given the rapid pace of change in the South and other regions. Care must be exercised, however, so that these permanent plots are not obviously marked or their location disclosed in order to avoid any biased treatment by land managers.

The cost of field data collection is approximately $350 per plot. Photo interpretation and data processing probably add another $50 per plot. Thus, in a State like

Mississippi, which has about 3,000 forested plots, development of data for a full State survey costs about $1.2 million.

PREVIOUS INVENTORY UPDATES

Over the years, at least two techniques have been used to develop updated estimates of State inventories. The first method was developed by Beltz and Christopher (1970) and applied to all Midsouth States (Beltz and Bertelson 1971). Severance tax receipts were used to estimate timber removals, and aggregate growth trends based on the previous survey were used to estimate increases in the inventory. No current area estimates were made. This, of course, was a major deficiency, especially when updates were made over long periods of time. This method does have advantages: it is relatively easy to apply; it can be designed for specific geographic areas (that include entire counties); and the inherent inaccuracies are usually not a major problem, unless there have been large and permanent shifts in forest area. Because of these advantages, this procedure is still used by various companies and consultants for updating volume estimates.

The next major effort at inventory updating took changing forest area into account and also involved remeasurement of permanent plots. Midcycle surveys have been conducted on five occasions in four Midsouth States (Van Hooser 1973; Thomas and Bylin 1982; Thomas 1985; Thomas and McWilliams 1985; and Beltz et al. 1987). These midcycle surveys used aerial photography to estimate forest area for entire states. Volume was estimated on the basis of remeasurement of a small proportion (10-12 percent for the later midcycle surveys) of permanent SO-FIA plots on the 3- by 3-mile grid. Current photography was used for forest area estimates, so the need for extensive ground checks was avoided. At an estimated cost of $150,000 to $250,000 for current photography, field work, and data processing, these midcycle surveys were cost effective for single States. However, the size of these costs and the time required for field work would preclude the application of midcycle surveys to several States on an annual basis. A satisfactory updating model must be able to provide current estimates for all Midsouth States for a given year.

DEVELOPMENT OF A NEW INVENTORY UPDATING SYSTEM

The new system for inventory updating has not yet been finalized, but principal elements are known and have been used in one system developed by Birdsey (1989) and applied to a survey unit in Arkansas. The State survey data will provide the basis for updating. Ancillary data will be utilized to a great extent: severance tax and other timber product output data will be used to estimate removals, and tree planting records will provide information about regenerated stands. A major factor to be incorporated is an estimate of current forest area from analysis of remotely sensed data. Development of area information is the current focus of remote sensing research at the SO-FIA unit.

An effective updating model must have the capability to provide current and detailed data on area, on volume by species group and by tree size class, and on growth and removals. The model must therefore have the capability to assess changes in trees on undisturbed areas, while also accounting for timber harvesting, forest regeneration, land clearing, and reversions. Accurate information about current forest area is essential to the entire updating process.

Information to be developed from remotely sensed imagery may be characterized at several different levels. The primary need is for developing reliable estimates of total forest area at either the survey region or the State level. As work progresses, data will be desirable for the following items: area by forest type, area harvested, area regenerated, and area by stand size. Eventually, research may be done on distinguishing volume classes and analyzing multi-resource attributes.

REMOTE SENSING RESEARCH AT SO-FIA

Remote sensing research has been under way at the Southern Forest Experiment Station for several years. Recently, priorities have focused on the use of remote sensing for updating inventories. Opportunities also exist to facilitate routine surveys.

Previous Research

Previous SO-FIA research using satellite imagery has involved Landsat data. One study in Puerto Rico evaluated the use of Landsat MSS data as a substitute for aerial photography in estimating forest area (Birdsey et al. 1984). That study demonstrated that Landsat MSS is a viable alternative to aerial photography for area estimation. For tropical areas where cloud cover makes it extremely difficult and expensive to obtain good photos, this may be an important use of satellite data. Landsat Thematic Mapper data has been used to classify forest types in two parishes in Louisiana (Teuber 1988a). In that study, estimates developed from classification of satellite imagery agreed with the standard SO-FIA estimates 75 percent overall. Mixed stands (oak-pine forest type) presented the greatest problem. Because mixed stands are common throughout the South, it is important that we improve our ability to detect them using satellite imagery.

Another study, which continues on a modified and expanded basis, uses Advanced Very High Resolution Radiometer (AVHRR) data for estimating total forest area at the State level. The initial study covered Arkansas, Louisiana, and Mississippi (Teuber 1988b). Analysis of AVHRR data produced estimates of forest area within 1 to 4 percent of recent SO-FIA estimates. Results for Louisiana, which differed from recent SO-FIA estimates by only 1 percent, also indicated a high degree of correlation between county level estimates generated by the two procedures. Further work must be concluded, however, before AVHRR data will be useful for routine inventory updating.

Current Research

A major project currently under way uses a multi-stage sampling approach to assess area and area trends in southwest Alabama and central Tennessee. This project is using AVHRR data (which has coarse resolution but low cost) in conjunction with Landsat TM data (which has relatively high resolution and high cost) to estimate total forest area and the change in the resource between selected times. A major consideration in using the two types of satellite data is the sampling design. A multi-stage approach will allow the advantages of both data types to be utilized in a fashion that will provide estimates of forest area and resource change of acceptable accuracy and at reasonable cost for SO-FIA purposes. Different techniques of detecting change will also be examined in this study. A GIS will be used in the study. The GIS will be used to store digitized aerial photographs to be used in ground-truth assessment and will provide a means to summarize results. A new survey is currently being conducted for Alabama, and a routine survey for Tennessee has recently been completed. These State surveys will provide additional information to facilitate completion of these studies, since an assessment of resource trends is a major focus of our routine surveys.

Assuming this method proves to be successful for estimating area and assessing resource change, application to an entire State will principally involve data processing costs and the purchase of TM coverage. AVHRR coverage for the entire Midsouth (one scene) costs only about $500. Complete TM coverage, which may cost $20,000 to $30,000 per State, may not be needed. In some cases, current photography purchased for other uses may be used instead. We are also exploring the potential of using aircraft-borne sensors that will provide detailed data, but at less cost.

Other studies are exploring related topics. One that is being conducted in cooperation with Mississippi State University is assessing the use of multi-seasonal imagery of forests in southwest Alabama. Preliminary indications are that winter scenes provide the most information, but use of data obtained in other seasons adds a great deal of information about forest type.

The SO-FIA unit is responsible for inventories on National Forest land. The usefulness of the surveys to National Forest personnel is a major concern. One current study has the objective of combining SO-FIA data with remotely sensed data, stand-level information from the district, and various other cartographic information in a GIS. It is anticipated that the combination of these data with GIS technology will provide information that is more useful than that obtained from each of these sources separately. We expect to apply the combination of remote sensing and GIS technologies to other situations.

Routine surveys often involve sending crews into remote areas that can be difficult or unpleasant to work in, such as the swamps and wetlands of southern Louisiana. The use of remote sensing to provide updated inventory information

for these areas would be very helpful in terms of work productivity and of safety. A study being completed by Louisiana State University on a cooperative basis is assessing the potential for using SPOT imagery, video, and 35-millimeter photography to estimate plot volumes for these remote areas. A related study, which is being conducted cooperatively by Louisiana Technological University, will determine the feasibility of using angle-gauge sampling of tree crowns to estimate volumes on plots similar to plots used in the regular SO-FIA survey. This technique, if successful, could be used in any remote timberland.

A final study undertaken cooperatively by Texas A&M University is using coarse-resolution AVHRR satellite imagery to produce vegetation maps of parts of Texas. This study deals with remote areas that are often only sparsely forested. The focus of this study is on vegetation cover, since much of west Texas is rangeland. The project is being conducted in conjunction with the Soil Conservation Service, which is responsible for inventorying nonforest land.

SUMMARY

The development of remote sensing and related technologies provides a good opportunity to update SO-FIA inventories on an annual basis. The use of digital imagery in combination with GIS technology and modeling procedures will allow the SO-FIA unit to improve the accuracy, frequency, and utility of the State-level surveys it conducts. An important factor in implementing the use of these technologies is cost. Procedures currently being developed should provide current estimates of important parameters within reasonable budgets.

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