Annual Forest Inventory
Cornerstone of Sustainability in the South

With many competing uses and large regional shifts in forestland use, the sustainability of southern forests is being questioned. The new Southern Annual Forest Inventory System (SAFIS) is being implemented to address regional, state, and national questions regarding past, current, and projected changes in the southern forest. The annual inventory system will provide the information needed to closely monitor and quantify the landscape dynamics of southern forests. These annual inventory data will form the basis of state, regional, and national forest sustainability assessments.

By Gregory A. Reams, Francis A. Roesch, and Noel D. Cost

The ecological and economic sustainability of southern forests is in question. Legitimate concern spans many public groups, from those concerned about maintaining biological diversity and the region's reservoirs of plant and animal genetic material, to forest landowners who manage forests to meet economic and societal needs, to average citizens interested in "doing the right thing," whatever that may be.

Changes in the management of public lands have significantly reduced the level of timber harvest on national forest lands (USDA-FS 1998). Timber removals in the South are projected to increase sharply over the next several decades in response to harvest reductions on western public lands (USDA-

Courtesy of USDA Forest Service

Hurricanes can instantaneously affect millions of acres of forestland. In 1989, Hurricane Hugo reduced the inventory of softwood growth stock by 21 percent in South Carolina (Sheffield and Thompson 1992). Annual forest inventories will provide nearly real-time estimates of change following catastrophic events.

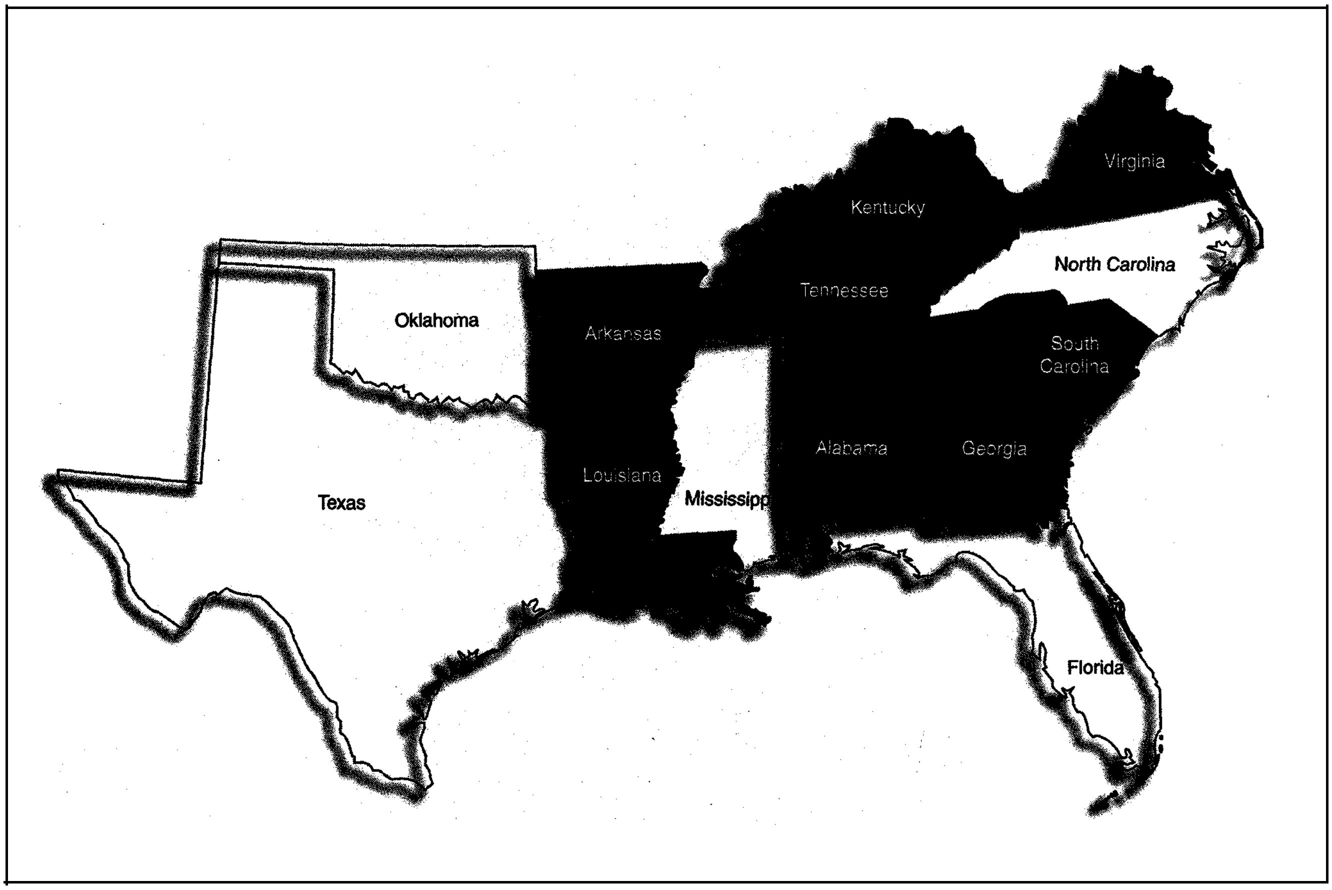

Figure 1. **By the end of 1999, eight southern states will be conducting joint state and federally sponsored annual forest inventories. All 13 southern states will likely implement the annual survey design by the year 2000.**

FS 1995). Current analyses of southern timber projections indicate that for some regions in the South, timber removals exceed growth (Cubbage et al. 1995). The question of whether the South can maintain or increase current levels of production cannot be answered at this time (Nilsson et al. 1999). After many decades of sustained inventory growth, southern inventories have leveled off. Increases in inventories are doubtful given the changing demographics and rapid urbanization of severa1 historically important timber-producing regions.

The sustainability of timber and wood fiber supply is only one of many components of the forest sustainability issue. Fundamental sustainability depends on ecosystem processes that work at varying spatial and temporal scales and humankind's use and alteration of the dynamics and functioning of forest systems (Smith 1970). An incomplete yet significant list of ecosystem stresses exerted by humans include land conversion, introduction of insects and disease, air pollution, and forest fragmentation. Humankind is suspected of contributing to climate change, which results in ecosystem stress.

Forest sustainability issues are not restricted to federal lands. Because nonfederal forests account for two-thirds of the nation's forested area, they will play the predominate role in determining the sustainability of not only the nation's forests but of our planet as well. The role of nonfederal forested lands is especially critical in the South, site of 41 percent of the nation's timberland; 92 percent of these lands are nonfederal. The South provides 67 percent of the nation's pulpwood, 50 percent of its plywood, 40 percent of its hardwood lumber, and 33 percent of its softwood lumber. Few of these production statistics are projected to decrease. The entire country is relying less on the timber resources on public lands, resulting in an increased dependence on privately held timber, particularly in the South. According to the most recent Resources Planning Act (RPA) projections of future demands for timber products, the consumption of pulp, paper, and paperboard will continue to rise and may increase by as much as 50 percent by the year 2040 (Haynes et al. 1995).

Estimating and maintaining current forest resources information is fundamental to providing real-time monitoring of forest ecosystems. The national Forest Inventory and Analysis (FIA) program of the USDA Forest Service is the primary source of information on the status, trends, and use of the nation's forests on public and privately owned lands. The FIA program is administered regionally by five research stations, with the Southern Research Station responsible for maintaining current inventories in 13 states, Puerto Rico, and the Virgin Islands (*fig. 1*).

To address the uncertainty of forest sustainability in the South, the American Forest & Paper Association (AF&PA), Southern State Foresters, and the Southern Governors' Association have recognized the need for a continuous forest inventory system. The AF&PA was instrumental in convening the second blue ribbon panel (BRP II) on FIA in October 1997. Key recommendations of BRP II include elevating the priority of the FIA program within the Forest Service, initiating annual inventories, reporting on al1 forestlands, and exploring partnerships for delivery of the program (AF&PA 1998). Since BRP II, the Southern State Foresters and the USDA Forest Service have collaboratively phased implementation of an annual forest inventory throughout the South. The Southern Annual Forest Inventory System (SAFIS) is the result of this partnership between southern states and the Southern Research Station's FIA program.

The initiation of SAFIS is an acknowledgement that the need for current information on changes in southern forests has never been greater. The need for maintaining current inventory information is evidenced by the Agricultural Research, Extension, and Education Reform Act (PL 105-185) (the Farm Bill) of 1998, which congressionally mandates FIA to implement an annual inventory system nationwide.

Past and Future Directions

A chronology of congressional mandates for forest resource assessments is useful for understanding the nearly 70-year metamorphosis of the USDA Forest Service's FIA program. The McSweeney-McNary Forest Research Act of 1928 directed the Forest Service to conduct periodic assessments of the nation's forest resources. The mission of this act was to estimate forest area, timber volume, growth, and cut. The forest inventories were charged with providing the information needed to formulate policies and principles for sustained forest use.

The McSweeney-McNary Forest Research Act led to the creation of the USDA Forest Service's Southern Forest Survey program in the 1930s. (Forest Survey later became the FIA program.) These initial forest surveys were key sources of information for the development of a fledgling pulp and paper industry in the South. Since then the program has continued to provide an unbiased public database that be can used by al1 citizens to estimate trends in forest area, distribution, species composition, and other vital forest statistics.

In the 1970s three pieces of legislation-the Forest and Rangeland Renewable Resources Planning Act of 1974, the National Forest Management Act of 1976, and the Forest and Rangeland Renewable Resources Research Act of 1978—expanded the objectives of the forest survey to include measurements related to wildlife, ecology, aesthetics, and recreation and other types of human impacts. The Farm Bill of 1998 mandated the Forest Service to implement annual surveys whereby 20 percent of FIA's one-sixth-acre ground plots are measured each year. These laws are in place to ensure the availability of accurate data and information for determining the sustainability of forest resources.

Since FIA's inception, the most basic goal of the program has been to provide a strategic survey that estimates total forest area and gives inventory estimates of broadly defined forest types. Examples include strata means and totals of forest types based on tree species composition, average stand age, tree size, and ownership. Changes in society's information needs have greatly influenced FIA and the use of its data over the years and will continue to do so. For example, key global climate change issues over sources and sinks of greenhouse gases in forests now are being investigated through the use of FIA data (Heath and Birdsey 1997).

The move toward national implementation of an annual forest survey has gained significant justification over the last several years. Annualized forest inventory systems fill the need for integrated assessments that rely on the best and most current data for identifying trends, relating trends to likely or suspected causes and consequences, and providing possible outcomes of alternative actions.

Regional assessments of resource trends have proved difficult under the traditional periodic survey system. Using the periodic system it takes 10 to 12 years to inventory the entire South, because the survey is implemented on a state-by-state basis. This approach can lead to the undesirable circumstance of bordering states having data that varies in age by a decade or more. Public users of southern FIA data have noted that these data are accurate for two or three years but become increasingly unreliable over time. With the rapid changes in the status and conditions of forestlands in the South, this system is inadequate. In addition, this system makes it difficult to observe trends, because plots can be remeasured at intervals of up to 15 years. In those cases it is entirely possible that important changes and trends are either missed or documented many years after they occur, which deprives decisionmakers of the opportunity to implement changes in management or policies.

There are benefits and costs associated with an annualized inventory system. Some of the benefits include current and uniform information across al1 states owing to a continuous and seamless sampling program that provides annualized monitoring of important resource trends across the entire South. Because identical sampling and modeling efforts are performed each year, catastrophic events such as hurricanes and insect and disease epidemics can be observed and accounted for on an annual basis. The greatest benefit ís that SAFIS provides data and methods for producing annual estimates, which provide critica1 information for effective policy and forest management decisions in the South.

On the cost side, compared to the periodic system SAFIS requires additional resources. In the periodic system, it takes an average of two years to collect the survey information for a state. Before SAFIS, the southern FIA program worked in two out of 13 states at any point in time. Under the periodic survey paradigm, about 8.3 percent of the plots in the South were measured in comparison to 20 percent as mandated by the Farm Bill. Additional resources are required to ensure the quality of the survey process, manage data, perform statistical analyses, and publish reports. SAFIS would not exist without the partnership between the Southern State

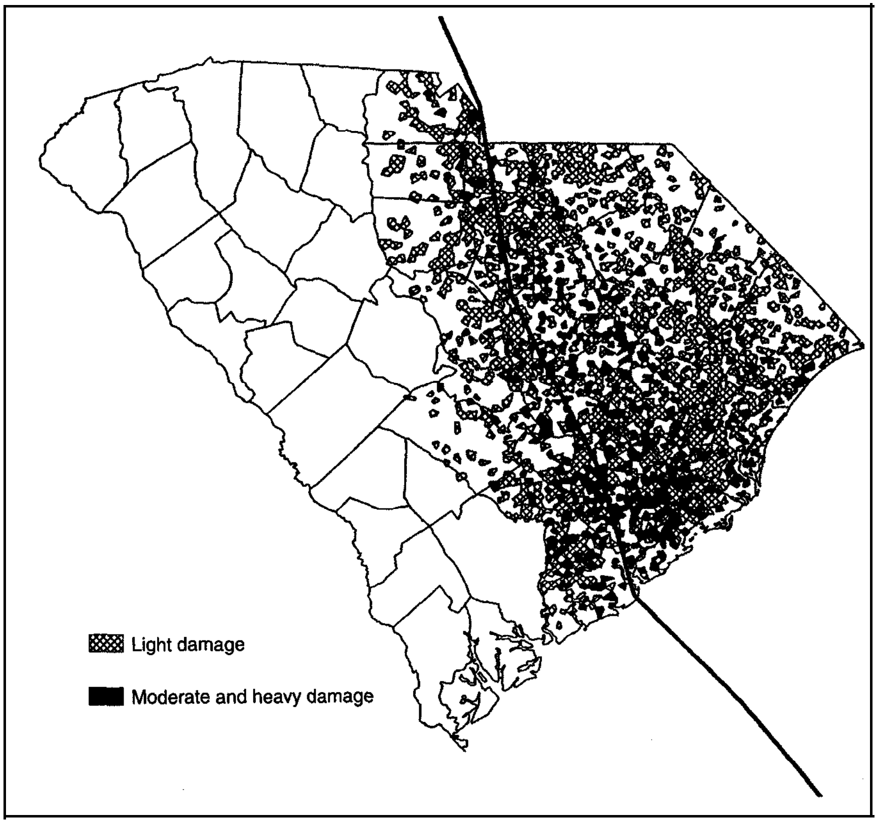

Figure 2. The distribution of forestland in South Carolina damaged by Hurricane Hugo, by degree of damage.

Foresters and the Southern Research Station's FIA program, which combines funds with intellectual and physical human resources. The annual survey is currently under way in eight states (*fig. 1*). Fiscal year federal dollars in 1999 for the operation of southern FIA include $8.2 million to the Southern Research Station, $1.2 million in federal cost-share to participating states, and combined state contributions (for Alabama, Arkansas, Georgia, Kentucky, Louisiana, South Carolina, Tennessee, and Virginia) of $2.5 million.

Design of SAFIS

In designing inventory systems it is important co recognize that definitions of sustainability change over time and vary according to location and interests. Changes in forest type and condition have accelerated, and the rapid pace of change likely will continue. The combined effect of real change and definitional changes calls for a resilient and simple sampling frame. This goal is in direct contrast to many operational timber inventories in which the sampling strategy is specifically tied to the efficient estimation of one or two closely related parameters of interest.

Fortunately for the continuity aspect of FIA, the types of measurements that are necessary to estimate forest resources are as valid today as they were 30 years ago, and it is unlikely they will change tomorrow. Facilitating recognized objectives and, as new resource questions emerge, introducing new ones into a long-term forest resource sampling design is of great importance, both technically and politically. Both aspects must be addressed because society's information needs are essential to defining the objectives of a federal inventory and monitoring program.

Another dominant consideration in planning a long-term monitoring program is the inevitability that a highly efficient sample design-one that optimizes on one or very few resources of interest-will go out of date. Examples in forest inventory include the use of stratification and variable probability of selection based on volume or value per unit area. Design features that involve complex sample structure create potentially serious difficulties, whereas an equal probability design permits greater adaptability and flexibility. To minimize sample design obsolescence, structure should be employed sparingly and with awareness of its undesirable effects; variable probability sampling designs and other complex sampling schemes are less amenable to the multiple and changing objectives that long-term monitoring programs must address, and therefore should be avoided (Overton and Stehman 1996).

Simplicity is desirable for many reasons. Not only will sample elements change over time (for example, a pine plot becomes a parking lot) but so will the overa11 objectives. Adding to the call for simplicity is the growing recognition that data collected from federally funded monitoring programs should be accessible to the public at large (Cowling 1992). With a relatively simple sample design, it is more likely that valid results and conclusions can be reached by various public users of the FIA database.

The simplicity and resiliency needs of the southern FIA program have resulted in the use of an equal probability systematic sample design (Roesch and Reams 1999). This interpenetrating design uses five annual panels, whereby plots measured in year 1 will be remeasured in year 6. In this mode of operation the survey cycle will always be one year, and the plot cycle will be five years. If funding difficulties occur it is likely that a smaller proportion of the plots will be measured each year.

Under the annual survey system, core data will be compiled each year into a standard set of tables for each state and released in hard copy and electronic formats. Data will be released within six months of the end of an annual measurement period.

Every five years a complete analytical report will be produced for each state. For the 13 states served by the Southern Research Station, two or three state reports will be prepared per year by the FIA program in collaboration with state, federal, academic, and other knowledgeable individuals.

Each state report will document the following: (1) the current status of the forest based on the last five years of data; (2) trends in forest status and condition over the preceding 20 years, with emphasis on comparing the most recent data with data from the previous period; (3) timber product output information for the state; (4) analysis and discussion of the probable forces causing the observed conditions; and (5) projection of the likely trends in key resource attributes over the next 20 years, under a range of plausible scenarios.

In the transition period from periodic design co ful1 implementation of the annual five-panel design, the following options for analysis and reporting are being considered: (1) produce estimates based only on those plots measured each year; (2) average the new panel information with the previous periodic information using moving average models; (3) complete the first two or more annual panels (at least 40 percent of al1 FIA plots) before reporting current inventory information. These options are being discussed because circumstances may dictate the reporting of information before the five-year analytical report is prepared.

Assuming a state does not receive new inventory information until al1 five panels are measured, some southern states will be relying on information that is 15 years old. At the very least the southern FIA program expects that a number of FIA customers will either use estimators developed by FIA for items 1 through 3 above or develop their own. Southern FIA believes it should provide statistical methods for developing interim estimates for public users.

Once the new rotating panel design has been fully implemented, the increased flexibility in inventory estimation techniques will be realized. Several approaches have been presented by the scientific community and are under investigation by FIA scientists and the externa1 users of FIA information (Van Deusen 1996; Reams and Van Deusen 1999; McRoberts et al., in press; Reams and McCollum, in press). Some of the methods can be implemented immediately, and several others will need further research and pilot testing before implementation is considered (McRoberts 1999; Roesch and Reams 1999).

New design features give rise to different and improved methods of analyses. However, new estimation methods usually undergo both a research and a user group development and phasing period. Annualized estimates that are most similar to the periodic system estimates will provide the foundation of first-generation annual inventory estimates (Roesch and Reams 1999). First-generation estimates will use rolling or moving average techniques based on averaging the last five years (panels) of data (Reams and Van Deusen 1999; Roesch and Reams 1999). Because inventory estimates are based on the five-year moving average, the perceived danger of mistaking fluctuations in estimates of inventory because of random sampling with real change is minimized. Based on a minimum number of assumptions, moving average methods have been shown to be identical to estimation techniques used by FIA under the periodic system (Reams and Van Deusen 1999). Second-generation methods that involve tree- and plot-leve1 modeling and other modeling updating techniques will be incorporated based on performance and utility to the program (McRoberts 1999; Reams and Van Deusen 1999; Roesch and Reams 1999).

There are circumstances in which the five-year moving average will overestimate or underestimate current inventory. These situations are most obvious when there is either an abrupt shift in inventory or a strong trend in the variable of interest. For example, if a hurricane similar to Hugo hit South Carolina during the measurement of panel 3, inventory estimates based on a five-year moving average would overestimate inventory in the eastern half of South Carolina&, 2). In this case, basing estimates on the two panels measured after the hurricane (panels 4 and 5) would be a reasonable alternative. Other possible solutions would be to use more-sophisticated time series models that can more readily account for trend or discontinuities in inventory.

Improved Assessments

Large-scale assessments of forest sustainability related co one or more major public policy themes or initiatives are becoming increasingly necessary. Well planned and executed annual survey systems can provide the basic initial baseline and monitoring information to address the many scientific and societal issue-driven assessments of sustainability.

Currently, the importance of forests and forest management to the global carbon cycle is a controversia1 subject being negotiated for the Kyoto Protocol co the United Nations Framework Convention on Climate Change. FIA survey data are used to estimate US forest carbon stocks so that sources and sinks of carbon can be identified. This represents a relatively new and unique use of FIA data and is certainly not a traditional one. Such use of these data would not have been predicted by inventory specialists even a decade ago. FIA data are the very foundation of US carbon stock estimates, and in al1 likelihood they will continue to provide the basic monitoring data for carbon stock changes both regionally and nationwide. FIA is the only national public database that can estimate and provide continuous monitoring of forest carbon stocks in the United States (Heath and Birdsey 1997; Joyce et al. 1997).

FIA data will continue to provide the basic information at the forest area, plot, and tree leve1 for al1 types of regional, national, and international forest assessments. National resource assessments such as RPA (Powell et al. 1993) and the recently completed Southern Appalachian Assessment (SAMAB 1996) rely heavily, in many cases exclusively, on FIA data to describe and estimate current conditions and trends of forests within a region. Annual information will allow for continued monitoring of forest resource trends and suspected causes addressed by the Southern Appalachian Assessment.

In the dual realm of strategic inventories and landscape-scale assessments, annual survey systems provide the information essential for monitoring resource conditions and trends. Annual inventory systems that are cost-effective, are publicly entrusted, and provide unbiased information of forest resource trends, are requisite for sound strategic planning, management, and conservation of the nation's forests.

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