VARIOUS ASPECTS OF SUSTAINABILITY ANALYSIS IN GEORGIA

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ABSTRACT.—In 2001 the Georgia Traditional Industries Program (TIP[3]) sponsored a cooperative study at the D.B. Warnell School of Forest Resources, University of Georgia, to analyze the long-term sustainability of the fiber supply in Georgia. The subject of this study is relevant to a diverse array of disciplines, and it offers the opportunity to explore various aspects of sustainability not directly related to the supply of fiber or timber alone. Examples of such aspects include studies of biomass densities and production, carbon densities, sequestration and credits, and landscape changes. We describe some of the technical aspects of data pooling and compilation, program settings and assumptions, and initial findings relating to this study.

BACKGROUND

Georgia, located in the southeastern part of the United States, is the third fastest growing State in the country, but over 72 percent of its land is still in forest cover. Over two-thirds of Georgia's forests are owned by approximately 630,000 private landowners. Forest production is Georgia's highest valued agricultural commodity and one in which it leads the Nation. Georgia has nearly 24 million acres in commercial forest (approximately 65 percent of the total 36.8 million acres), which is more than any other State. Georgia's forest industry generates 177,000 jobs: 75,000 jobs in the forest industry directly and the remaining jobs in industries supporting forest products manufacturing. The annual economic impact of the forest sector in Georgia exceeds a $21 billion contribution to the State economy through both domestic and foreign markets, while the value of the harvested forest products alone in 1996 was $1.22 billion.

Since 1993, Georgia has led the United States in the number of trees planted. In 1996-1997, over a quarter billion trees were planted in Georgia on almost a half million acres. In 1991, 2.6 million Georgians over 16 years old participated in some form of wildlife-related recreational activity, including fishing, hunting, and other non-consumptive wildlife activities. The economic impact of this recreation in Georgia was $1.1 billion. The growth of trees in Georgia is very rapid compared to other parts of the country. In addition, much progress has been made in the area of forest management intensification with use of herbicides and fertilizers. Modern pine plantations in Georgia that are intensively managed can grow up to four times faster than comparable extensively managed or unmanaged plantations.

The State's forest industry depends on accurate fiber supply assessments and the ability to predict changes in available inventory. With the rapid changes in the status and conditions of forests in the South, there is a need for more frequent inventory surveys. It is important also to monitor changes in land use, urbanization, fuel loading, balance of growth to harvest, and various catastrophic events. Recent efforts in obtaining more accurate and timely inventory estimates through reorganization of the Forest Inventory Analysis (FIA) inventory methods and through the

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implementation of the Southern Annual Forest Inventory System (SAFIS) reflect the importance of inventory updates for the forest industry and economies of the Southern States.

Forest inventory in Georgia is undergoing extensive changes in design, field practices, and applied technology. Rapidly changing technology and the availability of remotely sensed data offer new opportunities to enhance the inventory and its applications. Yet, even the most accurate and timely inventory cannot give a clear description of the future states of forest resources because such states depend on future actions and management practices, which in turn are subject to existing laws and regulations. To examine various states of our future forests, we need to consider multiple assumptions and alternative scenarios of forest management practices and potential laws and regulations. We can do this through long-term simulations of the changes that might affect our natural resources. In the described study, we investigated the potential impact of various assumptions and forest management scenarios on the future of the forest resources in Georgia using long-term simulations based on the current FIA inventory data and other available GIS and Landsat TM imagery.

DATA

Our analysis uses inventory data combined with GIS information and satellite imagery, hypothesized management and silvicultural practices, and various economic rules to define and evaluate the impact of various scenarios. The bulk of the Georgia data we have used so far came from the plot-level FIA database. We used the FIA variables describing polygon area, SI (site index), and stand age directly (Hansen and others 1992). A definition of species group used in simulations requires additional database processing separately for each simulation.

Until 2001, the primary FIA data site was handled by the Southern Research Station in Asheville, NC, and provided by its Web server as the Eastwide Database (EWDB) (Hansen and others 1992), and Westwide Database (WWDB) (Woudenberg and Farrenkopf 1995). In 2000, the Forest Service began switching to the new system making all FIA data from periodic inventories available as the FIADB database from the Web site of the North Central Research Station in St. Paul, MN (Miles and others 2000). In addition, we obtained Master Record (MR) data directly from the Forest Service (Southern Research Station, Asheville, NC). EWDB and WWDB databases (Hansen and others 1992, Woudenberg and Farrenkopf 1995) provide data from the last two periodic inventories for most of the States. Files in FIADB databases from the latest two periodic inventories were merged by conversion of EWDB and WWDB files to the same format. The structure was then extended to include space for the added variables in the new round of data collection. This new structure includes changes in the table design (seven tables instead of three), software for processing the data (Oracle™ database server), and a higher level of detail (all collected field variables are included in the database). The FIADB databases are also connected to the system for tables and maps creation called the Forest Inventory Mapmaker: http://www.ncrs.fs.fed.us/4801/FIADB/index.htm. MR data provide tree height measurements, but they are defined differently in different inventory cycles.

Our analysis requires information about the stands' expected growth and yield. This information can be approximated from available yield tables. Unfortunately, the available yield tables are often old, are not specific for various stand origins or cover types, and do not allow for simulation of intensive silvicultural treatments. One of the major problems is a lack of yield tables for deciduous species. Notwithstanding these limitations, every effort was made to obtain the most appropriate yield tables for each stand (e.g., Forbes 1961, Harrison and Borders 1996, Martin and Brister 1999, Nelson and others 1961, Pienaar and others 1996, Schumacher and Coile 1960).

ALGORITHMS FOR POPULATING THE PLOT DATA INTO STAND POLYGONS

Populating of the FIA data into forested areas was another challenge. Initially, we attempted to limit all the forested areas by polygons such that the boundary line between any two contiguous plots is midway between each respective FIA point, as illustrated on the example in figure 1. However, this appeared to be quite inconsistent with the areas that according to FIA analysis were supposed to be represented by each plot. In essence, each plot represents a certain acreage, which is expressed by each plot's area expansion factor. In the results of our first attempt, this was not the case since there is no connection between the polygon area and the area expansion factor of the plot. Therefore, we needed to develop an algorithm that included this plot expansion factor. To improve the data populating scheme, we incorporated additional information using county

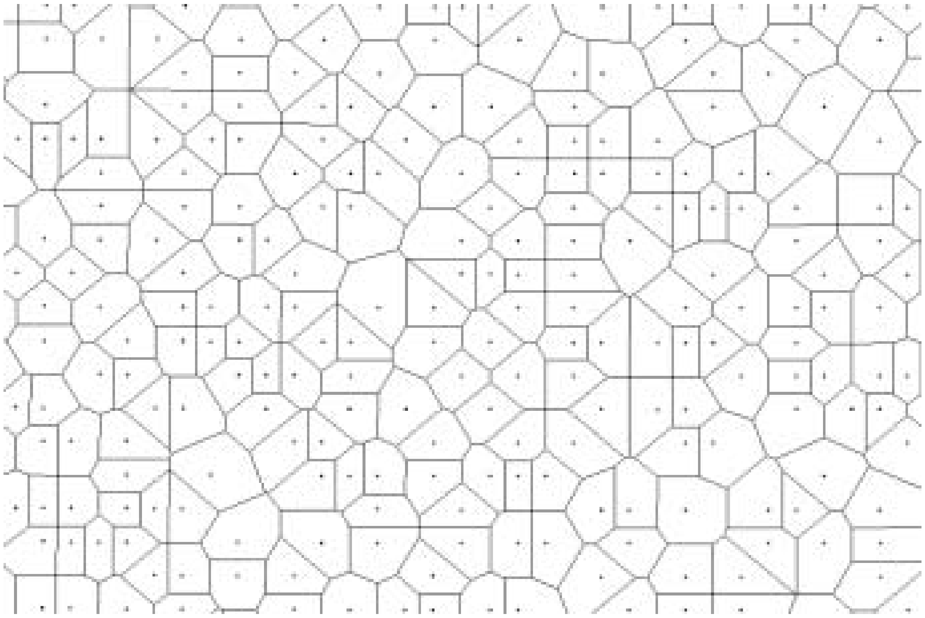

Figure 1.—*Populating of the FIA data using "mid-point" algorithm (polygons would have boundaries equally distanced from all surrounding FIA plots).*

boundaries, water resources, and road data. With this additional information the preliminary analysis was based on populating the FIA plots in circles of variable radii expanded around each plot but restricted by all the known boundaries and neighboring plot areas. Thus, the polygons around each plot were created by progressively expanding the radii until the area of the created polygons were equal to the areas represented by each plot according to the plot expansion factors established in the FIA program. Created in such a way, polygons were perfectly circular only in such instances where neighboring plots were not competing for common areas. In all other instances, expansion of the initial circular polygons was restricted in directions of the competing plots and counties, roads, and water resources boundaries, which resulted in generally irregular shapes of the polygons, as can be observed in figure 2. Further improvement in the spatial population of the FIA data was obtained using additional information available from the Landsat TM satellite images for the expansion of the plots and computing the expanded areas only according to the actual areas of existing forests (fig. 3).

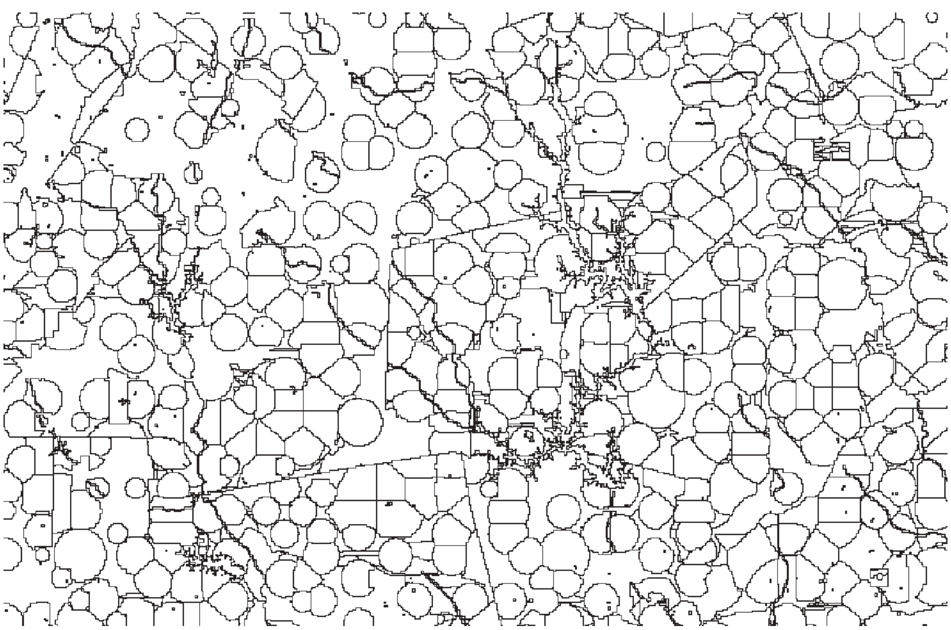

Figure 2.—*Populating of the FIA data using "circle" algorithm. The polygons around each plot were created by expanding the radii according to the plot expansion factors of FIA plots. Circular polygons are restricted in directions of the competing plots and counties, roads, and water resources boundaries.*

Figure 3.—*Populating of the FIA data using forest areas from Landsat TM imagery.*

SUSTAINABILITY ANALYSIS

For the sustainability analysis, we want to develop a methodology using Landsat TM, GPS, and GIS for fiber supply assessment on a short- and long-term basis. The main benefit of our study is expected to be in assessment and evaluation of various sensitivity analyses examining different levels of harvesting, regulatory constraints, and other methods of forest management. We run the simulations in annual time steps for 200-year periods. Such simulations produce useful information on sustainability of the current natural resources under various levels of utilization and statewide harvesting limits. We can also use them to assess impact of riparian zones, or buffers, around lakes, streams, rivers, and roads, as well as

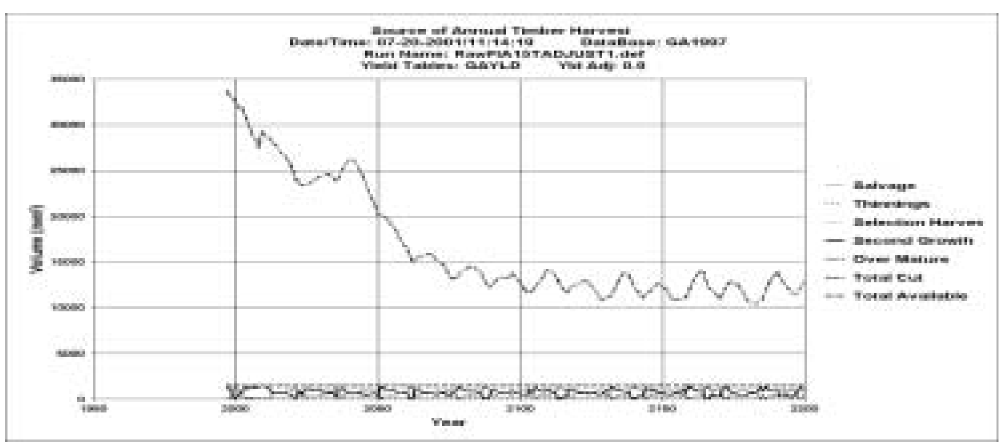

Figure 4.—*Example results of the simulations—source of the annual timber harvest at current volume cut level—1.5 million cubic feet per year.*

maximum harvest constraints, and adjacency and green-up constraints.

Initial simulations included simplified scenarios with three species groups, five site index classes, two yield tables, and various management regimes. The species groups were natural softwoods, planted softwoods, and hardwoods. The yield tables were for planted loblolly pine (Harrison and Borders 1996) and upland oaks (Gingrich 1971). Different management regimes were based on forest management practices and simulation objectives.

The simulations were conducted assuming three harvesting levels: one approximately equal to the removals in the latest FIA report (Thompson 1998), one 20 percent below the latest FIA report, and one 20 percent above the latest FIA report. The results of the simulations suggested that the current level of harvesting was sustainable (fig. 4) but that a 20 percent increased harvesting level would not be sustainable (fig. 5).

It should be pointed out that the impact of intensively managed plantations has not been allowed for in this preliminary analysis although intensive silvicultural operations in pine plantations of the Southeastern United States can increase productivity levels two to four times more than the productivity of more traditionally managed stands (Borders and Bailey 2001). Within the past 10 years, hundreds of thousands of acres have been put into this type of high production situation. Furthermore, hundreds of thousands of acres of agricultural land have gone into pine plantation production through the Conservation Reserve Program (CRP). Typical pine plantations in this CRP program are over twice as productive as non-intensively managed plantations established on cutover forest land (Pienaar and

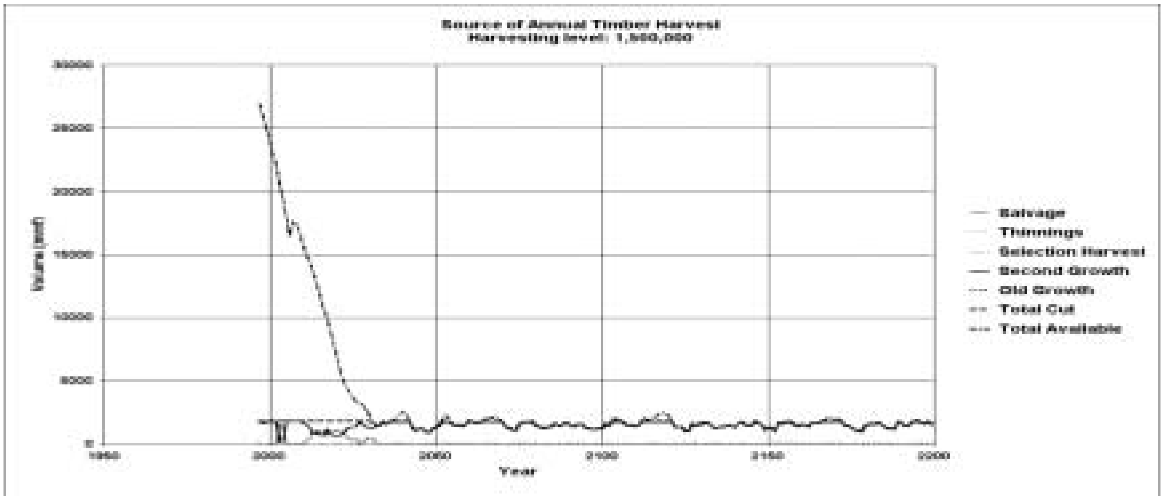

Figure 5.—*Example results of the simulations—source of the annual timber harvest at 1.8 million cubic feet per year—20 percent higher than in 1997.*

Rheney 1996). Together these two sources will contribute significant amounts to the available wood supply. Consequently, it is very important that we continue building additional growth and yield capability into the OPTIONS system so as to more realistically reflect the production of these important stand types.

CARBON BUDGET IN GEORGIA

In addition to carrying out sustainability studies as described above, we have developed spatially explicit estimates of the carbon and biomass pools for forests in Georgia (fig. 6). For this work we used individual biomass prediction equations available for various species in the Southeast. The equations were applied to each individual sample tree and above-ground woody stem and foliage biomass. Belowground biomass was estimated directly from aboveground biomass based on regression equations (Cairns and others 1997). Total biomass was defined as the sum of total tree woody, foliage, and root biomass. Biomass was converted to its carbon equivalent using a factor of 0.5 (Alexeyev and Birdsey 1998, Birdsey 1992) and expressed in Tg (10^{12} g). Such a partitioning of total biomass into total tree, foliage, and roots reflects differences in properties of tree components and in their role in the carbon cycle.

A stand is an aggregation of trees, and the stand biomass is defined as the sum of the biomass of the individual trees that make up the stand (Parresol 1999). According to this definition and the FIA database construction, we calculated tree, foliage, and root biomass per acre as a sum of the biomass calculated with regression equations for each sampled tree multiplied by its tree expansion factor. Values per whole state, each broad class, and weighted averages were obtained using appropriate expansion factors from the plot level.

The details of our study were reported in Cieszewski and others (2001a). A preliminary analysis of biomass pools (reproduced here based on the work of Cieszewski and others (In prep.)) is shown in table 1. Based on this work, total tree biomass of Georgia forests in 1997 was 842 million dry tons while biomass of foliage and roots was 29 and 186 million dry tons, respectively. Total biomass of all forests (sum of total tree, foliage, and root biomass) was 1,057 million dry tons. Foliage makes up less than 3 percent and roots make up about 18 percent of total forest biomass of the State. Total tree biomass of hardwood species is 493 million dry tons, which is approximately 59 percent of the total biomass of all forests. However, hardwood species account for less than half (47%) of total foliage biomass (table 1). Since root biomass was calculated as a proportion of the total tree biomass, the proportion of hardwood root biomass relative to all species' root biomass is the same as the hardwood proportion of aboveground biomass (58%).

Through the GIS capabilities of OPTIONS, we can track the carbon budget spatially over time to produce projected carbon pools using a methodology similar to that described above and in Cieszewski and others (2001a). This capability will undoubtedly be useful in evaluating various management and policy decisions and their impact on carbon sequestration in forests.

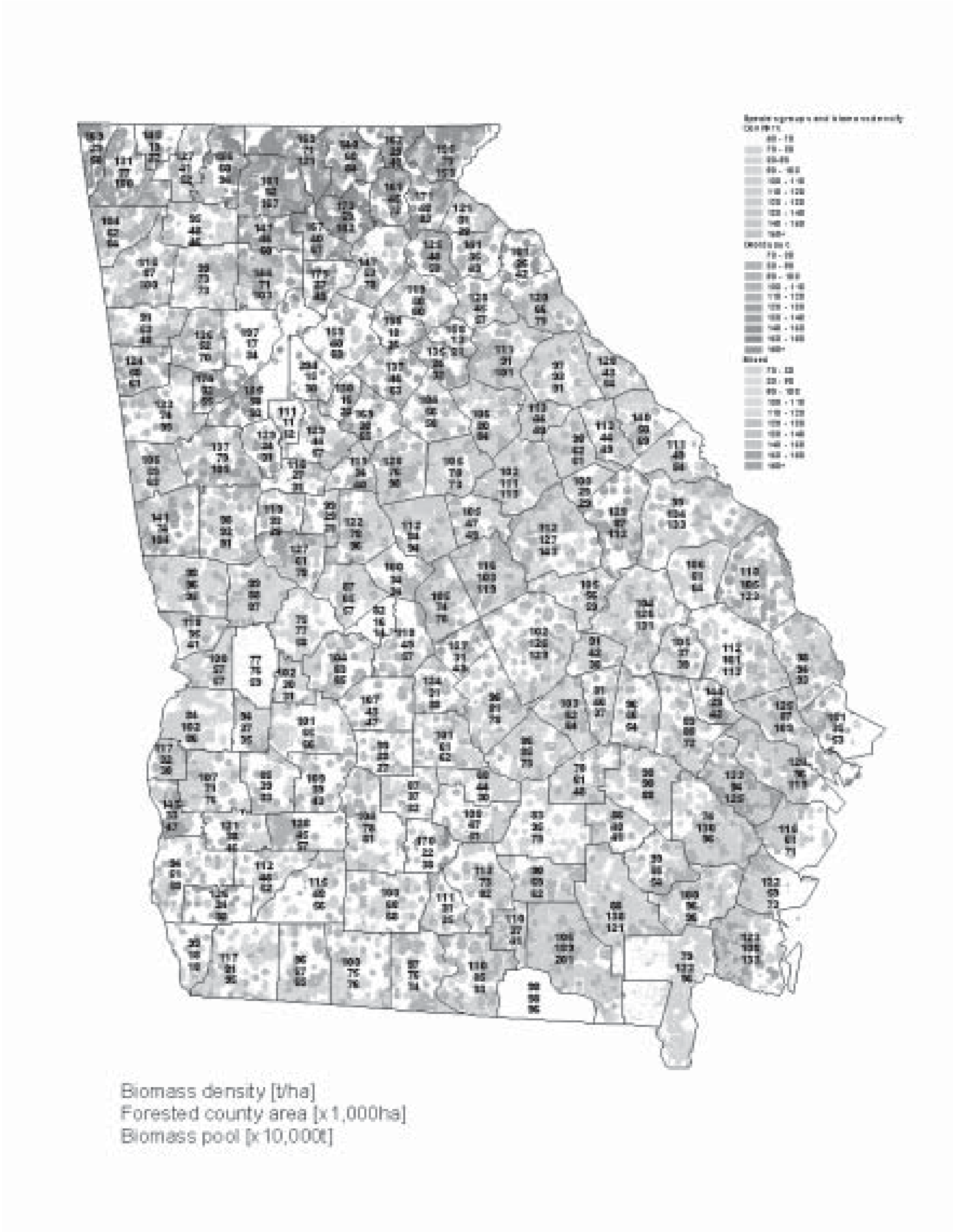

Figure 6.—*Biomass density [t/ha] by species groups on the plot level of resolution in Georgia. Numbers are biomass density [t/ha], area [x 1,000 ha], and carbon pool [x 10,000 t] on the county level of resolution, respectively.*

Table 1.—*Detailed analysis of dry biomass distribution calculated from FIADB*

	Tree		Foliage		Roots		Total	
	mil. t	%	mil. t	%	mil. t	%	mil. t	%
Species groups								
Hardwood	515	59	14	47	112	58	641	59
Softwood	352	41	16	53	80	42	448	41
Forest type								
Evergreen	344	40	15	50	79	41	438	40
Deciduous	410	47	11	37	88	46	509	47
Mixed	113	13	4	13	25	13	142	13
Sum of component's		100		100		100		100
Biomass [mil. dry tones]	867	79	30	3	192	18	1,089	100

SUMMARY

The described study is designed to allow for simulations of various scenarios of forest management as well as to study the impact of regulatory constraints. As such, we are using and customizing the OPTIONS estate-planning model (by D.R Systems Inc.) for the Southeastern United States.

This large-scale long-term sustainability analysis involves many difficult technical aspects, some of which still pose unsolved problems. To date, progress in conceptualization of this project includes interim solutions for populating inventory plot data into realistic spatially explicit stand inventories, which can be used for simulation of long-term statewide simulation in forest resource management and utilization. Furthermore, we are continuing to add more stand-specific growth and yield capabilities, which will provide more realistic simulations.

Finally, we have shown that carbon budgets of forested areas can be estimated and projected using the OPTIONS estate-planning model. This capability will make this tool an essential component for evaluating management and policy impacts on future carbon pools.

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