

A COMPARISON OF TIMBER INVENTORY PROJECTION METHODS WITH TRIM AND GRITS: APPROACHES, APPLICATIONS, AND IMPROVEMENTS

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INTRODUCTION

Timber inventory projection models form the basis for timber supply, demand, and price forecasts. These regional or national inventory/supply models have been a driving force behind most national policy debates regarding timber supply adequacy for decades. They also have been tested for use in local or subregional applications for locating or expanding forest products mills or assessing forest resource conditions. Several timber inventory models have been developed in the United States by the Forest Service and by other institutions.

This paper examines the structure and applications of two timber inventory projection models--TRIM and GRITS--that have been applied for local areas in the South, and their projections for two forest survey units in southern Georgia. TRIM--the Timber Resource Inventory Model--is the Forest Service national timber inventory projection model and was used in the South's Fourth Forest study timber projections (U.S.D.A. Forest Service 1988); its updated version (ATLAS) was used in the 1989 Forest Service RPA projections (Haynes 1990). GRITS--the Georgia Regional Timber Supply Model--was developed at the University of Georgia and used to project local timber inventories in the state or elsewhere. This paper compares the methods used in the two models, which provides a basis for future improvements.

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TIMBER SUPPLY MODELS

Timber supply models can be considered to include both economic market models, where supply is a function of demand and price; and timber inventory models, which merely project timber inventories through time given predetermined timber prices and removal levels. TRIM and GRITS are timber inventory projection models. TRIM has been linked with the general Timber Assessment Market Model (TAMM) for use in national Renewable Resources Planning Act (RPA) analyses. GRITS has not yet been linked with a market model, although we currently are working on linking it with the Sub-Regional Timber Supply (SRTS) model.

Timber inventory models have been used in two basic applications. The most common use is to develop inventory models for small regions to examine questions regarding the adequacy of local timber supplies. Usually this type of application addresses questions such as; "Can current harvest levels be sustained?". The other type of application is to use inventory models to shift supply in an economic market model. This type of modeling is associated with the RPA timber assessments. In timber inventory models, harvest levels are set exogenously. In timber market models, harvest is modeled as the result of supply/demand equilibrium in the stumpage market. This paper will discuss market models as the background for timber inventory projection methods, and then discuss current inventory models.

Market Models

TAMM.--The current U.S. Forest Service national economic model of timber markets is the Timber Assessment Market Model, or TAMM (Adams and Haynes 1980). TAMM is an economic "spatial model of North American softwood lumber, plywood, and stumpage markets designed to provide long-range projections of prices, consumption, and production trends" (Adams and Haynes 1980). Various demand regions and supply regions are contained in the model. Stumpage demand depends on the end products for which it is used. Exports, fuelwood, and miscellaneous products also are relevant. Product recovery factors, which vary by region and type of product, are also significant determinants of derived stumpage demand.

SARIM.--The focus of RPA timber assessments is national policy, though regional issues are often studied (e.g. the spotted owl). Policy makers interested in more detailed analysis of local issues have usually resorted to the non-economic timber adequacy studies described above. For the South's Fourth Forest study (U.S.D.A. Forest Service 1988), the Forest Service attempted its first disaggregation of regional projections to the state level.

In the Fourth Forest study, TAMM, TRIM, and the Southern Area [land] Model (SAM) were used to project regional timber supplies for the South from 1990 to 2030, in a top-down approach to inventory projection. The results from these projections were then disaggregated into state level data using a State Allocation of Regional Inventory Model (SARIM) that was developed by Abt (1989). SARIM is an accounting model that disaggregates regional trends so that timber area, growth, removal, and inventory

information could be obtained for each state in the South. This set of complex economic, land area, and inventory models were used in the Fourth Forest study to project timber inventories, harvests, stumpage prices, wood products consumption and production, and employment in the forest products sector for the long term of 50 years. The projections were based on biological and economic assumptions and data and the ensuing equilibrium between timber supply and the demand for stumpage.

SRTS.—While the Fourth Forest "top down" approach to state modeling provided additional information, it was constrained to be essentially a partitioning of the regional projection. The approach allowed only limited use of state inventory information and it was not possible to investigate state-specific scenarios. For example to increase harvest in one state meant that harvest had to be decreased in another state to maintain consistency with the regional projection.

To address these limitations, the Subregional Timber Supply (SRTS) Model was developed (Abt and Kelly 1987). The model links separate regional inventory models by modeling harvest and price response to supply shifts. The model shifts harvest in response to inventory change, calculates the price effect of projected harvest, and allows harvest to shift among regions in response to price change. Since there is little economic information on the local price and inventory elasticities, the model facilitates sensitivity analysis to examine changes in the economic assumptions.

The SRTS/TRIM application that is the basis of comparison here was developed to model the north Florida/south Georgia stumpage market. TRIM models discussed before were developed for three Florida survey units (central and south Florida survey units were combined) and the two coastal plain survey units in Georgia. The SRTS component of the model shifted harvest between ownerships (forest industry and other private) and regions through time. In general harvest shifted to industry ownerships in northeast Florida and southeast Georgia. Though several harvest scenarios were modeled, the results from the scenario that continued current harvest levels are reported here.

Inventory Models

TRAS.—The first modern national United States timber inventory projection model that was developed was TRAS, or the Timber Resource Analysis System. TRAS was a computer program that culminated about 15 years of Forest Service research designed to project changes in timber volume in response to net growth and timber removals. TRAS was developed to meet the needs of the Forest Service to update inventories to a common date for periodic national compilations of timber resource statistics, to help analyze and interpret changes in the timber resource between surveys, and to project future timber supplies under alternate management assumptions (Larson and Goforth 1970, 1974).

Larson and Goforth (1970) described TRAS as follows:

"TRAS is a comprehensive computer program that calculates the annual change in numbers of trees by 2-inch diameter classes. Annual change is obtained by subtracting annual removals and mortality from the annual increase in numbers of trees in the absence of cutting or mortality. This

annual increase in numbers of trees or potential increase is estimated for each 2-inch class from a functional relationship between diameter at breast height (d.b.h.) and number of trees. Thus, an average annual increase in diameter is related to a corresponding increase in numbers of trees."

TRAS was used as recently as in the United States 1979 Renewable Resource Planning Act (RPA) timber projections. In this application, TRAS separated stands into regions, ownership classes, and softwood and hardwood components. The two species group components were projected separately. The total stand basal area was projected to change in proportion to the basal area of the projected component. Inventory change was simulated annually by changes in the number of trees in the stand table and the acreage of commercial timberland. The potential increase in the number of trees in each diameter class is based on radial tree growth rates estimated for each diameter class and on the rate at which small trees grow into the smallest merchantable diameter class--termed ingrowth (U.S.D.A. Forest Service 1982). This approach makes accurate measurement of the number of stems important.

The ingrowth rate is particularly influenced by the growth of young plantations and by natural regeneration following harvest very important. In the late 1970s, considerable concern was expressed that an inadequate amount of trees in the 2-inch and 4-inch diameter classes would lead to future timber shortages.

Timber Resource Inventory Model.--The next evolution in national timber inventory projections and supply modeling was the development and adoption of the Timber Resource Inventory Model (TRIM), and its linkage with the Softwood Timber Assessment Market Model (TAMM). TRIM was a timber inventory projection model developed by researchers at Oregon State University, and then maintained and updated by the forest economics research work unit at the Pacific Northwest Research Station. TRIM is a yield table projection system that simulates timber growth, inventories, management and area changes, and removals over the projection period (Tedder et al. 1987). TRIM consists of three scanning programs and an inventory projection program. Scanning programs process the initial inventory, yield and management information, and stand organization and removals information. The actual inventory model processes a random access file containing all the information of the previous input files to project changes in timber inventories (Figure 1).

TRIM is fundamentally different from TRAS in its projection methods. TRAS simulated growth and yield by changing the number of trees in 2-inch diameter classes. In the TRIM system, the inventory is aggregated into 5-or 10-year age classes, and growth is simulated by the use of yield tables and an approach-to-normal algorithm to project stand yield trajectories. TRIM is a large accounting system that uses input parameters for growth, yield, and harvest actions to account for site, stand age, and density characteristics, and to project inventories (Mills 1989). The TRIM model also uses the approach to normality concept to increase volumes in stands that are less than fully stocked. The TRIM approach-to-normal coefficients are flexible enough to allow for fast or slow rates of change that approach the yields to a normality, or even be switched off so that volume in fact will follow a path of growth parallel to the yield table. Either normal or empirical yield tables can be used in TRIM (Mills 1990).

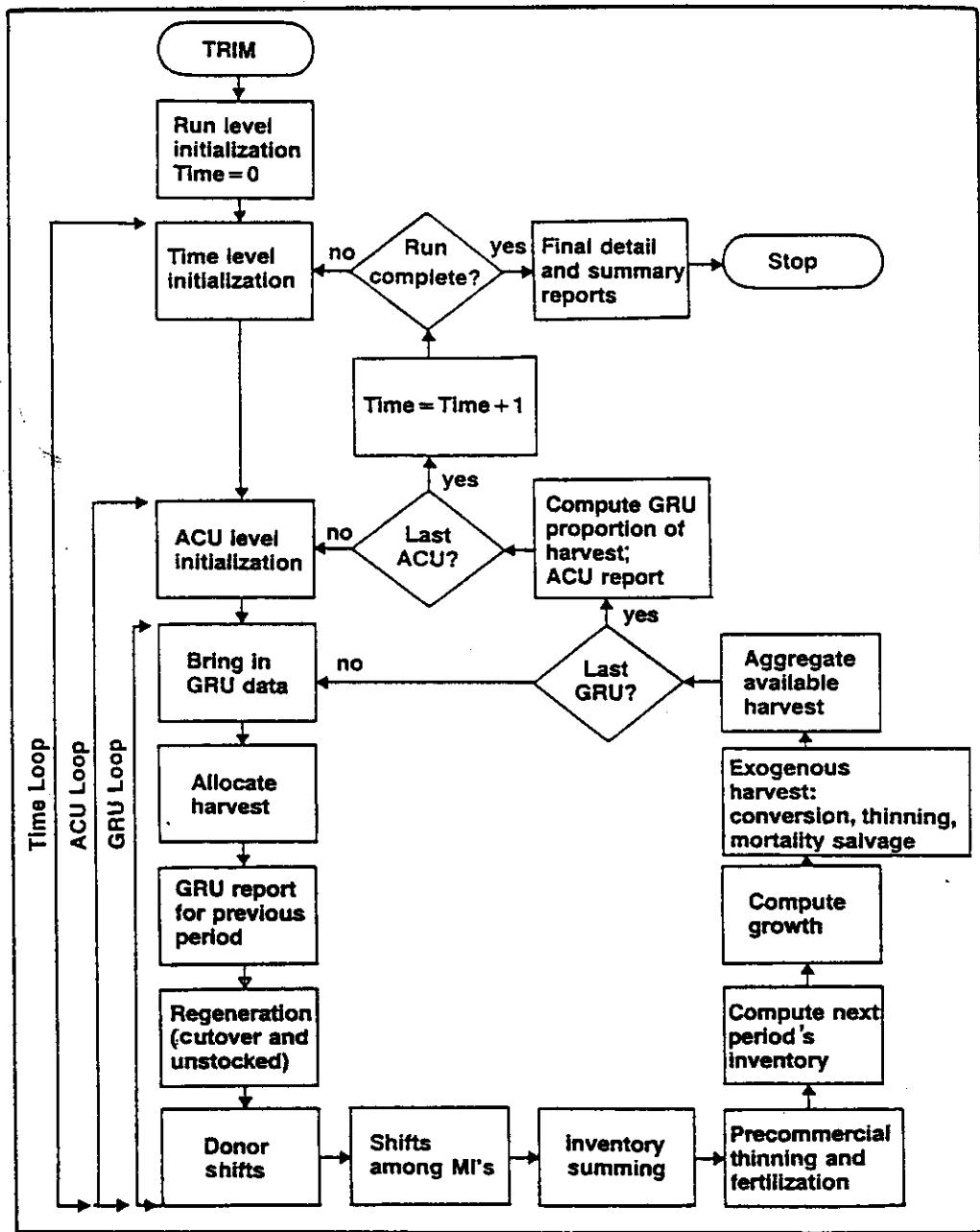


Figure 1. TRIM Logical Flow Outline

The TRIM system has many options, making it complex but flexible (Mills 1989). For example, in the South's Fourth Forest study (U.S.D.A. Forest Service 1988), inventory was aggregated by two geographical areas, six ownership groups, five species types, and three site productivity classes. Fifty-four cells of acres and volume per acre were available for each inventory unit, and each also had four management class codes. Each ownership-type-site-inventory unit could be represented by 126 cells, so that the 180 forest survey units in the South had potentially 22,680 different forest resource cells, although not all of these possibilities were employed.

Aggregate Timberland Assessment System (ATLAS).--The Aggregate Timberland Assessment System (ATLAS) is the updated version of TRIM, and is currently used for national timber inventory projections. In the TRIM model applications for the South's Fourth Forest study, only clear-cutting was used to simulate harvests of timber, with harvests being allocated to the oldest stands first. However, partial cutting accounts for roughly half the harvest on nonindustrial private forest lands in the South-Central United States (McWilliams 1990). Thus ATLAS was tested with partial cutting in recent analyses.

ATLAS was employed in the 1989 RPA projections, and is referred to as TAMM90/ATLAS (Haynes 1990). The U.S. was divided into eight timber supply regions, each region was further divided into ownership, forest type, and productivity classes. In total, the 1989 RPA projections employed 249 management units, and 84 management units had more than one management intensity. Furthermore, 422 yield tables were used in the 1989 RPA timber projections (Mills 1990).

The Georgia Regional Timber Supply (GRITS) Model.--The basic premise underlying the GRITS model was similar to that of a stand growth projection model, where timber inventories were advanced through time based on their initial inventories and growth and removal rates (Cubbage et al. 1990, 1991). A stand growth projection model advances individual trees through diameter classes based on average diameter increment (Davis and Johnson 1987). GRITS advances regionally aggregated timber volumes through age classes. This average volume increment was applied assuming a uniform distribution of inventory in each age of the class, similar to the uniform application of a diameter increment in a stand table projection. This annual volume increment (growth per acre) was lowest for the 0 to 10 age class stands, and increased as stand age classes increases, up to about 30 to 50 year classes, depending on the management type. Thus volumes in each age class are grown at a different rate as they progress through time.

The GRITS model is based on a Lotus 1-2-3 spreadsheet template to enter the data by region and forest management type (Figure 2). Lotus macros control the program execution and a separate PASCAL program is used to make the projections. Input data categories include area, inventory, growth, and removals by region, management class, species group, and age class. These input tables can be obtained in already summarized tables from the Southeastern Forest Experiment Station Forest Inventory and Analysis (FIA) work unit. Once the basic data are entered, one must use the GRITS Lotus template to run the program, the PASCAL program to project supplies, and the Lotus template to import the projections and print the results.

Each timber table divided all volumes into several classes. The regions represented the forest survey units or other substate breakdowns. The hardwood/softwood species groups divided FIA inventory volumes into these two broad classes. The five principal management types are those usually reported by the FIA work unit--planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods. Even pine plantations contain some hardwood volumes; similarly, hardwood stands contain some softwood volumes. FIA age classes were divided into 10-year classes, and for nonmanaged stands; this also is based on common FIA reporting practices. Nonmanaged stands are those stands which have stocking levels too low to manage for timber production, although considerable timber inventories and harvest volumes do occur in this class.

Growth, Removals, and Area

The key factors that drive any inventory projection model are timber growth, timber removals, and forest land area changes. Some of the approaches that were used in TRIM/SRTS and GRITS differ considerably. Both models start with the initial inventory and area as reported by the FIA forest surveys. They then use various methods for projection.

Growth.--TRIM and GRITS used a similar principle for projecting growth through time. Both models used a fairly simple approach of projecting existing forest inventory volumes through a stand table projection/empirical yield table approach. In both, the current inventories by species or groups were divided among age classes in an initial volume table. In addition to this initial volume table, each had a corresponding "yield" table that summarized the growth per acre for each of the species/age class combinations. TRIM usually used empirical yield tables by species that could be entered by the users. GRITS, instead, used average growth per acre per year by broad species group for the region.

Each of the five GRITS management classes--planted pine, natural pine, mixed pine-hardwood, upland hardwood, and lowland hardwood--had average annual rates per acre for both hardwoods and softwoods. For example, pine plantation softwood growth rates in the Southeast were about 13 cubic feet per acre per year for the 0-10 age class; 126 cubic feet per acre per year for the 11-20 age class; 157 cubic feet per acre per year for the 21-30 age class; and 125 cubic feet per acre per year for the 31+ age class. The plantation softwood timber inventory in each age class was then "grown" each year using these annual increment rates. One-tenth of the base acres in each age class strata was transferred into the next strata each year, where it would then be grown at the new annual increment rates unless cut. TRIM used a similar approach to transfer inventory volumes through cells, only it grew the volumes in each cell at the relevant local empirical yields for a number of individual species, not broad species groups like GRITS.

In GRITS, all growth was based on the broad regional averages for softwoods and hardwoods (separately) by broad species group and age class. TRIM used the empirical yield tables. It also used the approach to normality coefficient, which can adjust the empirical yield tables upward over time, on the assumption that stands become more (or

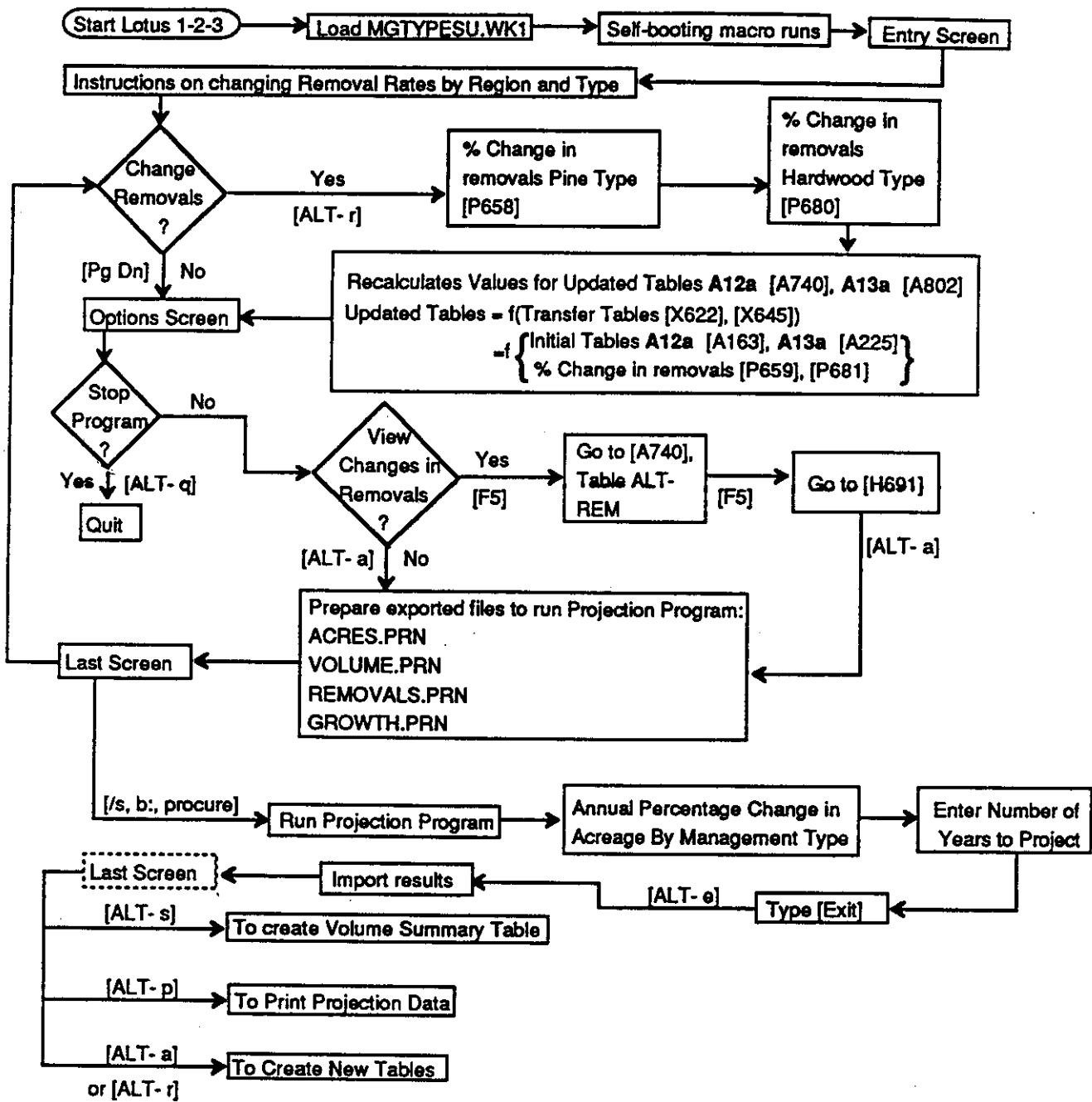


Figure 2. GRITS Logical Flow Outline

less), fully stocked. Growth in TRIM/ATLAS is computed as a function of the yield table and an assumption about the rate of approximation of actual volumes to the yield table volumes.

Changes in the removals, area change, yield tables, and approach to normality coefficient serve as a means to calibrate or adjust the TRIM results to arrive at a "reasonable" first projection; this base case would then be used in future projections. GRITS did not use any normality or other adjustments, but simply relied on broad average forest growth rates as they occurred, so was not calibrated to achieve target inventories. GRITS projections could be modified by changing growth rates or harvest rates in the input data, as could the TRIM projections. GRITS uses annual growth per acre, so it is an annual model. TRIM and ATLAS are not necessarily annual models; their projection period is based on the number of years in the age classes considered in the data.

Removals.-- Removals by period are input by the user in TRIM. TRIM removals default to harvesting oldest age classes first, or may be distributed across age classes by the user. The TAMM removals were taken out of the oldest age classes by species in the South's Fourth Forest research. The removals in GRITS are based on the historical removal levels, distributed across age classes, as determined by FIA survey data, and are held constant over time in the base runs, although they can be adjusted by users if desired.

In the Florida/Georgia SRTS/TRIM application, removals by region, ownership, and management type were determined exogenously based on the SRTS model. In the GRITS Georgia application, removals among region, species group, and management type were set at constant rates based on the historical rates determined by the FIA data.

Area.--Forested land area is the third key variable in timber inventory projections. In the South's Fourth Forest study, the TRIM land area changes were determined by the Southern Area Model (SAM). These land area changes may be determined by owner class, management types, or a number of other factors. GRITS used aggregate annual land area changes by forest management type--pine plantation, natural pine, etc.--in projecting timber supplies. In the Georgia applications, land area changes were determined by the change in areas of forest types during the prior surveys.

In order to project timber supplies at a substate level, GRITS was used in Georgia for many regions. These included the five forest survey units used by FIA in the state, and subdivisions of three of these units. These divisions were made on the basis of factors likely to affect local supply, including mill location, transportation, and demographics. The large and crucial Southeastern and Central Survey Units were subdivided. So was the North Central Unit, where the Atlanta metropolitan area affects available timber supplies and wood fiber transport.

SOUTH GEORGIA TIMBER PROJECTIONS

In a pair of independent studies performed in the 1980s, GRITS and TRIM were used to project timber inventories for the two southern Georgia survey units. Cabbage et al. (1991) developed and used GRITS with 1982 FIA data to project inventories for all

survey units in Georgia, including the Southeast and Southwest. Abt et al. (1991) obtained TRIM and used it to project timber inventories in northern Florida and the two southern Georgia survey units. In addition to TRIM, the projections by Abt et al. used their SRTS Model to incorporate economic components into the inventory projections, and to shift removals among regions based on relative price indices.

Both the TRIM/SRTS and GRITS applications in South Georgia had their initial harvest levels set based on existing FIA removal estimates in the region. For GRITS, the initial removals in each region were held constant over time. For TRIM/SRTS, the harvest level for all regions in total remained constant, but this total was distributed differently among regions each period based on the relative prices determined by the SRTS model.

These two studies projecting inventories in South Georgia allowed us to compare the results of two different approaches. Unfortunately, these comparisons proved not to be as similar or as elegant as we hoped. Nevertheless, let us at least try to make some observations about model projections, differences, and applications.

The projections we made with the two models differed in several respects, which made direct comparisons of the results impossible. The GRITS projections were made for softwood and hardwoods and for the five forest management groups. "Softwood" included all softwood species, including cypress, white pine, and red cedar. "Hardwoods" included all broad-leafed species. The TRIM/SRTS projections were run with only southern pine species as their softwood component (cypress and juniper were excluded), and only the upland hardwoods and mixed pine-hardwood stands as their hardwood component. Cypress and other softwoods were lumped in with hardwoods. Pines and hardwood volumes were projected but only pine inventories were used to shift harvest in SRTS. On mixed stands, both pine and hardwood volumes were projected. Bottomland hardwoods were not included.

The GRITS and TRIM/SRTS projections were both made with the 1982 FIA inventory, growth, and removals data. Unfortunately, the 1982 data had significant errors in the growth and removal rates due to an erroneous computer algorithm, which was not discovered until about 1989. GRITS used the faulty input data, so was unlikely to forecast well.

One other factor prevented unbiased comparisons between the models. The TRIM/SRTS 1982 projections were not actually made until after the preliminary 1989 South Georgia data were released. Abt et al. used the 1989 data to calibrate their results from the 1982 projections—that is they configured the projections from 1982 to exactly equal the actual 1989 inventory, growth rates, and removal rates. GRITS was completed before the 1989 data were released, and could not have been calibrated to exactly match them anyway.

The long term TRIM/SRTS and GRITS projections are interesting (Table 1). For softwoods in the Southeast, TRIM showed a slight drop in timber volumes in 1985, and then a rapid build-up from 1990 to 2010. GRITS showed a substantial decline until the year 2000, and then a more modest volume increase. For the Southwest, TRIM projected

Table 1. Comparison of TRIM and GRITS Inventory Projections for Southern Georgia Survey Units

	<u>TRIM/SRTS</u>		<u>GRITS</u>	
	<u>Softwood</u>	<u>Hardwood</u>	<u>Softwood</u>	<u>Hardwood</u>
Southeast	-----million cubic feet-----			
1980	4,045	-	-	-
1982	4,016*	-	5,125	3,270
1985	3,973	-	4,686	3,294
1990	4,067	859	3,952	3,250
2000	4,666	641	3,735	2,982
2010	5,741	247	4,226	2,867
Southwest				
1980	1,758	519	-	-
1982	1,733*	-	2,129	1,266
1985	1,696	512	2,134	1,280
1990	1,641	470	2,040	1,273
2000	1,709	355	1,838	1,254
2010	1,997	318	1,674	1,256

*Interpolated

decreasing volumes until 1990 and increasing volumes from 2000 on. GRITS projected modestly decreasing volumes from 1985 on. Overall, the softwood inventory levels projected by GRITS were somewhat smaller than the TRIM/SRTS projections. TRIM/SRTS also allowed the substitution of timber from northern Florida, which would prevent large inventory decreases. GRITS used the incorrect FIA growth and removal data, which were furthest off in the Southeast Georgia Survey Unit.

The TRIM/SRTS hardwood numbers were not useful for trend comparisons, since they reflected only a portion of the volume. The GRITS hardwood projections showed slightly decreasing hardwood supplies in the Southeast survey unit and fairly stable supplies in the Southwest.

CONCLUSIONS

This comparison of the TRIM/SRTS and GRITS models has provided some insights about how the models work and their merits, but it could not really make direct comparisons about their accuracy. Both models were used to project timber inventories in the two southern Georgia forest survey units, but their inputs differed significantly. The TRIM/SRTS approach included only pines, and used SRTS to shift harvest volumes among the South Georgia and North Florida survey units in response to increasing prices. The Florida researchers also used the 1988 FIA available to exactly calibrate their projections from 1982. GRITS did not use an economic component to modify harvest pressure (although SRTS is actually being linked to it as well), and could not be calibrated for matching a target 1988 inventory level. Thus, we were unable to make a direct TRIM and GRITS inventory projection accuracy evaluation.

Of the two models, GRITS is easier to use and requires less start-up time. Researchers at Georgia and several firms have used GRITS to make local timber supply projections. GRITS can be used iteratively to produce projections that incorporate the results of previous runs, allowing for changes in removals, areas, or starting inventories. Since GRITS is a spreadsheet template it can be modified to suit specific needs of the user. We currently are testing a combined GRITS/SRTS model for local projections.

GRITS only provides aggregate volumes by forest management type and by softwood/hardwood species groups. TRIM is more complex, but is able to provide more detail on volumes by species and by ownership class. One could use GRITS to get ownership class breakdowns by running twice for the same area, only with different owner input data. One could also subtract out the inventory from a known source--e.g. company lands. The GRITS and SRTS approaches are best for bottom-up supply modeling. TRIM/TAMM is a mostly top-down modeling approach and better for detailed national studies. GRITS is useful for short-term, local inventory projections. SRTS can be used to allocate harvest levels among small or large regions.

Overall, the search for the holy grail of inventory projections models will continue. Neither TRAS, TRIM, GRITS, or ATLAS can be considered perfect timber projection models. In fact, considerable room for improvement exists. It is interesting to note that while one thinks of timber yield models as being the work of biometricians, it is economists or FIA personnel who have developed and maintain most of our national

timber projection models. Our discussions with colleagues who are biometricians have generally found an abhorrence of the methods used in TRIM and GRITS, coupled with a unwillingness to build superior models. Several have suggested that using individual tree or stand growth models would be superior, but none felt that the data management problems were easily surmountable at a regional or national level, and none appear interested in developing national or regional models. Improving the existing models or developing more elegant new models will continue to be a challenge for forest economists, biometricians, and policy makers.

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