Incorporating interstate trade in a multi-region timber inventory projection system

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Abstract

An interregional trading model for roundwood products was developed that recognizes the importance of demand centers (centers of forest products manufacturing activity) and inventory in forecasting future harvests and trade flows. A gravity model was constructed that considers the relative position of each region vis-a-vis all others as a producer of stumpage and as a consumer of roundwood products. The gravity model was incorporated in a multi-region version of DPSupply (Teeter 1994, Zhou and Teeter 1996, Zhou 1998) referred to as the Interregional DPSupply System (IDPS). Projections for growth, harvest, and trade in forest products were made for the 13 states of the southern region through 2025. Aggregate trends in inventory are similar to those reported in the Southern Forest Resource Assessment (Wear and Greis 2002). Inventory trends by product (pulpwood, sawtimber) and type (hardwood, softwood) differ by state and are used to illustrate the advantages of explicitly recognizing intelTegional trade in the projection system.

The South is the major timber production region in the United States. In 1997, nearly 58 percent of U.S. industrial roundwood and three-fourths of total U.S. pulpwood was produced in the region (Smith et al. 2001). A number of projections made in the 1970s and 1980s (Haynes and Adams 1985), as well as the 2000 USDA Forest Service RPA Assessment (Haynes 2003) predicted an increasing share for the U.S. South both in timber growth and in removals.

This paper describes an interregional timber inventory projection model that recognizes the importance of demand centers (centers of forest products manufacturing activity), inventory dynamics, and trade flows in forecasting future harvests. The model adapted work by Teeter et al. (1989) who modeled interindustry trade and highlighted the interdependence of producing regions. Drawing from that work, a gravity mOdel was constructed that considers the relative position of each region vis-a-vis all others as a producer of stumpage and as a consumer of roundwood products. As a result, the model allows for changes in the harvest levels among regions to accommodate imbalances in inventory, changes in production capacity, and transportation costs from the source of the raw material to manufacturing facilities.

An Interregional DPSupply Model

The Interregional DPSupply (IDPS) model utilizes a combination of normative and positive approaches (Wear and Parks 1994) to modeling timber supply. It models growth and optimal management decisions on the level of individual representative stands (FIA sample plots). The optimality criterion for management decisions is maximization of land expectation value (LEV). By aggregating representative stands available for harvesting to the subregional level, supply is modeled for four roundwood products: softwood pulpwood,

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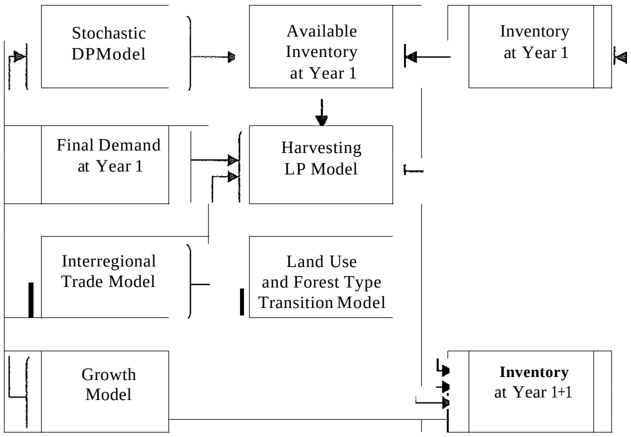

Figure 1. - The structure of the Interregional DPSupply system

softwood sawtimber, hardwood pulpwood, and hardwood sawtimber. IDPS allocates demands for individual products in the demand subregions among the supply subregions using a gravity coefficient method.

At the core of the IDPS model are three main components: a stochastic dynamic programming (DP) model for determining optimal harvesting decisions, a linear programming (LP) harvestIllg model, and an interregional trade model (Fig. 1). They depend on several supporting models, including stand-level growth models, roundwood products distribution (merchandizing) models, and land use and forest type transition models. Extending DPSupply (Teeter 1994, Zhou and Teeter 1996, Zhou 1998) to incorporate the 13-state southern region requires accounting for 1) regional differences in growth, the anticipated products from representative stands and management type area change; and 2) the roundwood trade among states in the region. To accomplish the first goal, the region was divided into five physiographic regions similar to those identified by Bailey (1995) including the coastal plain, the piedmont and mid-coastal plain, the mountains and interior plateaus, the Mississippi alluvial basin, and the western piedmont and mid-coastal plain. The second goal was accomplished by creating a model of interregional roundwood trade based on the fixed gravity coefficient method (Leontief and Strout 1963).

At the data-preparation stage, the following steps were performed. Regional growth models, product distribution models, and matrices of optimal management decisions were constructed for five key forest management types (planted pine, natural pine, oak-pine, lowland hardwood, and upland hardwood) for each ownership class (forest industry and nonindustrial private forest [NIPF owners]) within each of the five specified physiographic regions. We used data from FIA sample plots to construct the regional growth models and regional product distribution models. Growth was modeled using methods similar to those used in Zhou (1998) and consisted of sets of polynomial equations using tree and plot level FIA data. Product distribution models to allocate the projected volumes on each plot among the four roundwood product classes were constructed using the multinomial logit methods outlined by Teeter and Zhou (1999). The product distribution models allowed us to merchandize stands according to the four product class descriptions as well as provide information to the harvesting module regarding volume available by product class.

The DP module is run for each region utilizing the regional stand level growth models, the stand level roundwood products distribution models, and a stochastic model of future stumpage prices (Teeter et al. 1993). By maximizing the net present value. of growing timber, the DP model produces a matrix of optimal management decisions for each possible combination of stand descriptors (physiographic region, ownership class, forest type, mean diameter at breast height [DBH], and mean volume) at each of five stumpage price levels. Details of the DP module are presented in the "Optimal management decisions" section later in this paper.

Our models to predict land use and forest type changes are based on the FIA sample plots data. Details are presented in the "Area change" section later in this paper. Finally, we generated matrices describing the trade flows of each of the four roundwood products considered in the model between all pairs of the 13 southern states (see "Modeling future trading activity in forest products" later in the paper).

For each year of the projection period, the following sequence of steps is performed. All stands in current period inventory are assigned optimal management decisions by matching each stand's attributes (physiographic region, ownership class, forest type, mean DBH, and mean volume) with the attributes of the stands modeled in the DP. If the optimal management decision for the given stand at a particular price level is harvesting or thinning, this stand is considered available for harvesting at that price level. By aggregating roundwood product volumes of the stands available for harvesting to the state level, we obtain inventories of roundwood products available for harvesting in each state at each of the assumed price levels.

Using assumptions (scenarios) about the annual rate of increase in the consumption of roundwood products and the previous year's consumption levels, we calculate current year consumption levels for each roundwood product in each demand state. The interregional trading model (see "Modeling future trading activity in forest products" section) redistributes these demands among the supply states. Linear programming procedures allocate the consumption-level requests (demand) among the stands available for harvesting in the supply states (see "Allocating harvest" section).

The harvested area is then assigned to one or more forest management types depending on the stands' pre-harvest forest management type and ownership class, with areas of new stands determined proportionally to the values of transition probabilities generated by the land-use/type change model. Initial area of the stand in this model is equal to the area represented by each forested plot in the PIA inventory, approximately 5,000 to 6,000 acres depending on the state. Stands that are not harvested and those stands that are thinned are then "grown" 1 year using the growth models, resulting in the next year's initial inventory.

Data

Constructing the IDPS model for the US South required the following data:

- Forest Inventory Analysis (FIA) inventory data by sample plot for each of the 13 states in the region. The data were obtained from the USDA Forest Service website (www.ncrs.fs.

fed.us/480 1/FIADB/fiadb_dump/fiadb_dump.htm, accessed November 10, 2002) and included the following inventories: Alabama-1990, Alabama-2000, Arkansas-1995, Florida-1987, Florida-1995, Georgia-1989, Georgia-1997, Kentucky-1988, Louisiana-1991, Mississippi-1994, North Carolina-1984, North Carolina-1990, Oklahoma-1993, South Caro1ina-1986, South Carolina-1993, Tennessee-1989, Tennessee-1999, Texas-1992, Virginia-1984, and Virginia-1992.

.. Timber Product Output (TPO) data on production, consumption, and trade of major timber products for each of the 13 states of the U.S. South. The data were obtained from bulletins of the USDA Forest Service Southern Research Station, for example, Johnson and Steppleton (2001), Bentley et al. (2002), Johnson and Brown (2002).

.. Stumpage price data, collected by Timber Mart-South (Norris Foundation 1977-2001).

Methods

Modeling future trading activity in forest products

As an economy develops, goods produced in one region are often sold in another region of the country. Several groups of methods exist for regional interdependence analysis. One group includes fixed trade coefficient models (multi-regional input-output models), and another includes linear programming models.

There are a several obstacles to using linear programming for modeling interregional trade of roundwood products. First, application of linear programming in the context of spatial models requires a large number of parameters to support the analytical mechanisms of interregional trade. These parameters include demand and supply prices and quantities in each of the demand and supply regions, as well as the costs of transportation between each pair of demand and supply regions. Unless prices and quantities in demand and supply regions are exogenous to the model (e.g., Holley et al. 1975), the problem cannot be solved using linear programming procedures. This difficulty was somewhat overcome by using reactive programming, an iterative procedure that computes the equilibrium solution using a series of successive approximations (Adams and Haynes 1980, 1996). Other researchers have used nonlinear programming, as in the FASOM model (Adams et al. 1996), or linear approximation of a nonlinear objective function, as in the PELPS model (Lebow et al. 2003).

However, the more serious constraint to using linear programming in the case of roundwood trade is the uncertainty regarding actual transportation distances. Leontief and Strout (1963) noted that trading regions are usually more or less extended areas, so the average distances between them do not do a good job representing the actual diversity of trade flows. Furthermore, typical transportation distances for roundwood products are of a similar order of magnitude as the size of the trading regions. The heterogeneous nature of certain roundwood products, in particular differences in the quality of hardwood sawtimber not captured by available trade statistics, might add complexity to the problem. As a result, transportation costs cannot be determined with the accuracy necessary for the application of linear programming procedures.

Finally, yet importantly, cross-hauling, or the simultaneous shipment of a homogenous commodity in both directions, is difficult to incorporate into linear programming models (Polenske 1980).

Fixed trade coefficient models utilize empirical trade relationships between industries and the regions themselves. These models are based on the assumption that the total of interindustry demands (including the industry itself), plus demands by final users plus exports equal the industry's output. Fixed trade coefficient models were designed as rough and ready working tools capable of making effective use of limited amounts of information (Leontief and Strout 1963). In forest economics, these models were used by Teeter et al. (1989).

Within the fixed trade coefficient framework, interregional trade is accounted for using one of three models: a column coefficient model, a row coefficient model, or a gravity coefficient model. When modeling interregional trade, the column coefficient model and the row coefficient model focus on regional demand and regional supply, respectively. We selected the gravity coefficient model because it allows us to model trading relationships more realistically by capturing interaction effects among the supply and demand regions.

According to the gravity coefficient model (Leontief and Strout 1963), the amount of interregional trade is proportional to the total production and total consumption of the commodity in, respectively, the supply and demand regions, and is inversely proportional to the total amount of the commodity produced in all regions:

$$X_{gh}^{i} = \frac{X_{go}^{i} X_{oh}^{i}}{X_{oo}^{i}} Q_{gh}^{i} \ \forall \ i,g,h, \qquad [1]$$

where i, g, h = product (i), production regions (g), and consumption regions (h); X_{gh}^{i} = amount of product i shipped from region g to h; X_{oh}^{i} = amount of product i shipped to region h from all regions; X_{go}^{i} = amount of product i shipped to all regions from region g; X_{oo}^{i} = total amount of commodity i produced in an economy; Q_{gh}^{i} = gravity coefficient.

Depending on assumptions about the nature of the spatial interaction between supply and demand regions and data availability, gravity coefficients can be either extracted from the base-year data or detetmined using exogenous variables (Hua 1990). Because trading regions are relatively large and irregular, and data on production, consumption, and trade of roundwood products between southern states are available, we determine gravity coefficients from the base year data according to the point estimate procedure (Leontief and Strout 1963).

In order to incorporate the dynamics of timber inventory in our product trade model, we needed to make a modification of the model shown in Equation [1]. Remember that the gravity coefficient method assumes that trade between two regions is proportional to the total production of the commodity in the supply region. Since from the previous work (Binkley 1987, Abt et al. 2000) we know that the elasticity of roundwood supply with respect to timber inventory is commonly assumed equal to 1, we will assume in this effort that roundwood supply is proportional to inventory. Consequently, it is also reasonable to assume that the shipments of roundwood product i from region g to region h are proportional to the amount of wood available for harvest in region g. Now, modifying Equation [1], the amount of timber product traded will be:

$$X^i_{gh} = \frac{X^i_{oh} I^i_g}{X_{oo}} \hat{Q}^i_{gh} \quad [2]$$

where $\hat{Q}^i_{gh}$ = "modified" gravity coefficient; I^i_g = amount of roundwood product i available for harvest in supply region g.

Stability of technological and interregional coefficients is the basic assumption of input-output and multi-regional input-output models. Polyakov (2004) demonstrated that interregional gravity coefficients for the trade of pulpwood in the U.S. South are temporally stable. Assuming the "modified" gravity coefficients are also stable, the model allows prediction of harvest and trading levels in each forest product for future periods, based on the regional demands and the amounts of wood available for harvesting each year of the projection.

Optimal management decisions

The assumption of the DP component of the IDPS model is that forest owners manage their forests in order to maximize net present value over an infinite series of rotations. Although the importance of this objective for NIPF owners has often been questioned, work by Newman and Wear (1993) supports the basic assumption. Another assumption is that forest owners bear replanting costs at the beginning of the rotation and receive income when thinning occurs or at the end of the rotation, when they sell stumpage. Because replanting is assumed only for pine plantations, for all other forest types income at final harvest is the only component of cash flow.

The immediate return from thinning or final harvest is evaluated using the product distribution (merchandizing) models at each of the five levels of stumpage prices. Stumpage prices fluctuate over time, therefore expectations of future prices influence forest owners' harvesting decisions. For this reason, a stochastic pricing element, similar to the one developed by Teeter et al. (1993), was incorporated in the IDPS model to produce more realistic outcomes, i.e., other things being equal, owners are more likely to offer timber for sale when the price is higher because of the expectation that it will fall in the future. As a result, more stands will be offered for harvesting at higher stumpage price levels, reflecting our general market assumption of an upward sloping aggregate supply curve.

The general backward recursive equation for our stochastic DP model is:

$$\begin{aligned} V_t = \max_k \{ & \Pi_t(P_t, d_t, v_t, k, o_l, f_m, r_n) \\ & + \beta E[V^*_{t+1}(P_{t+1}, d_{t+1}, v_{t+1}, o_l, f_m, r_n) | P_t]\} \quad [3] \\ & \forall P, o_l, f_m, r_n;\ l = 1,2;\ m = 1, \ldots, 5;\ n = 1, \ldots, 5 \end{aligned}$$

where V_t = value function (\$/acre); k = decision variable -- management decision at time t (clearcut, thinning, selective harvest, or no action); d = the stand's DBH (183 0.1-in classes); v the stand's volume (209 25 cf/ac classes); P = level of softwood sawtimber stumpage price (5 levels from \$0.70/cf to \$2.10/cf); o_l = ownership (NIPFs or industry); f_m = forest type (planted pine, natural pine, oak-pine, lowland, or upland hardwood); r_n = physiographic region (the coastal plain, the piedmont and mid-coastal plain, the mountains and interior plateaus, the Mississippi alluvial basin, and the western piedmont and mid-coastal plain); Π = immediate net return of management decision k (\$); β = discounting factor (we used a 5% interest rate for NIPFs and 7% for industry); E = an expectation of the optimal value function in the future period V^*_{t+1}, which is a probability weighted value function of future decisions at random future prices P_{t+1} conditional on current prices P_t.

The output of the DP model is a matrix, which identifies the optimal management decision for each combination of DBH and volume within each ownership class, forest management type, and physiographic region, and at each of the stumpage price levels. The lowest price level at which the optimal decision for a given stand would be harvesting or thinning can be interpreted as the producer's (forest owner's) reservation price level. Using the stand's volume per acre and its product distribution, we calculate reservation stumpage price per acre (W) for each of the stands available for harvesting.

Allocating harvest

With a completed decision matrix from the DP model, the harvesting simulation can begin marching through time. For each year of the projection period, harvest levels for each product in each state are determined using available inventory, final demands, and the interregional trade coefficients produced by the interregional trade model. The linear programming model then allocates the harvest request (demand) for each product in each state among the stands available for harvesting by choosing those stands that have an appropriate mix of products and can be harvested at the lowest price:

$$\begin{aligned} & \min_{s_{gj}} \sum_{g=1}^{G} \sum_{j=1}^{N_g} W_{gj} s_{gj} \\ & \text{s.t.} \sum_{j=1}^{N_g} v^i_{gj} s_{gj} = \sum_{h=1}^{H} \frac{X^i_{oh} \sum_{j=1}^{N_g} v^i_{gj} S_{gj}}{\sum_{h=1}^{H} X^i_{oh}} \hat{Q}^i_{gh} \quad \forall g,i \quad [4] \\ & 0 \le s_{gj} \le S_{gj} \quad \forall g,j \end{aligned}$$

where G = number of supply states; N_g = number of stands in supply state g; s_{gj} = area (a portion) of stand) in the supply state g selected for harvesting or thinning (decision variable); W_{gj} = reservation stumpage price (\$/acre) for stand) in the supply state g; v^i_{gj} = volume of product i in stand) (cf/ac); S_{gj} = total area of stand) ($\sum_{j=1}^{N_g} v^i_{gj} S_{gj}$ is equal to I in Equation [2]); X^i_{oh} = demand for product i in the demand state h; $\hat{Q}^i_{gh}$ = gravity coefficient calculated from the base year trade data.

Area change

Area change in the projection system uses a method similar to one utilized by Zhou et al. (2003) (their Scenario 1), where land use and forest management type changes are derived from the historical FIA data. The method has three integrated components:

1. Area gained by each forest management type from non-timber land
2. Area lost by each forest management type to non-timber land
3. Area gained/lost by one management type through transition from/to another management type

In order to model components 1 and 2, all FIA plots were selected that had non-timber land as the previous land use type and one of five forest management types as the current land use type, or those having one of the five forest management types as the old land use type and non-timber land as the current land use type. Plots representing public ownership were not included in this analysis. These plots were grouped by forest inventory unit. For each forest inventory unit, loss and gain by forest management type were calculated. Based on the length of a unit's survey period, annual gain was calculated and future gain was modeled by annually adding the appropriate proportion of acres to each forest management type by FIA unit. Net loss was modeled by adjusting (decreasing) the area of timberland annually. Timberland area was unifonnly reduced across the region to reflect the effect of streamside management zones based on the findings of Wu (1994).

To model transitions between forest management types, all FIA plots where harvesting took place during the survey period were selected. The probability of transition was modeled using a multinomiallogit model. The probability that a new (current survey) forest management type would be a particular type was assumed a function of the old (previous survey) forest management type and the ownership class associated with the plot. Transition probabilities were calculated for each forest management type by physiographic region.

Results

We used the IDPS model to project growth, harvest, and trade in forest products for 13 states of the southem region for the period 2000 to 2025. Furthennore, we compared IDPS projections with the projections of the Subregional Timber Supply (SRTS) model used in the Southern Forest Resources Assessment (Wear and Greis 2002).

Inventory adjustment

As previously mentioned, the most recent FIA inventOly data were collected in different years for different states, ranging from 1988 (Kentucky) to 2000 (Alabama). The consequence of using this kind of base data are that results of projections could be biased if those state inventories were used as initial conditions for projections. One of the features of this study is that timber inventory data were adjusted from the year of the latest FIA to the base year, 2000, using the IDPS model. We used Southern Pulpwood Production annual reports (e.g., Johnson and Steppleton 2001) and interpolated data from Timber Product Output reports (e.g., Johnson and Wells 1999) to determine annual harvest levels for these adjustments.

Aggregate inventory projections

We examined three different scenarios regarding future patterns of consumption of wood products (by firms) in the southern region using the IDPS model. These scenarios are: 1) no change in the level of forest products consumption from its level in 2000; 2) a 0.5 percent annual increase in consumption of forest products; and 3) a 1 percent annual increase in consumption. The 0.5 percent annual increase scenario, considered here as the base case scenario, is consistent with the EL (elastic demand, low increase of plantation growth rate) scenario of the Southern Forest Resource Assessment (Wear and Greis, 2002). In that analysis, despite an assumed 1.6 percent annual outward shift of timber demand, the removals level during the period 2000 to 2025 increased 0.60 percent annually due to assumptions of elastic timber demand. The 1.0 percent increase in consumption scenario reflects trends similar to those shown by the IH (inelastic demand, high plantation growth rate increase) of the Southern Forest Resource Assessment (Wear and Greis 2002), which shows a 1.03 percent annual increase of removals during the period 2000 to 2025.

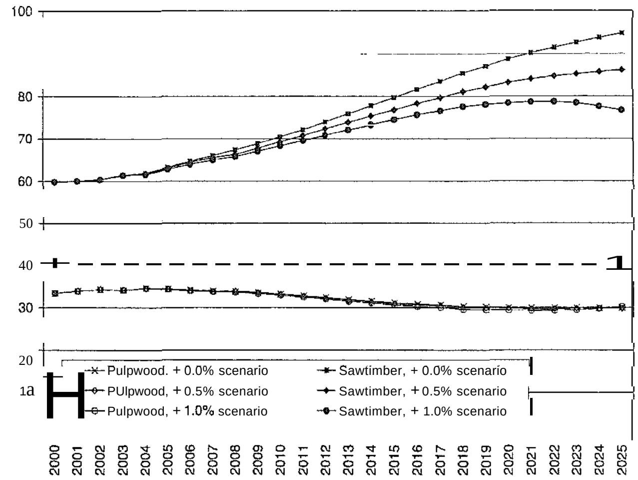

Figure 2. - Softwood inventory projections for the 13-state southern region under three harvest increase scenarios, 2000 to 2025 (billion ft^3).

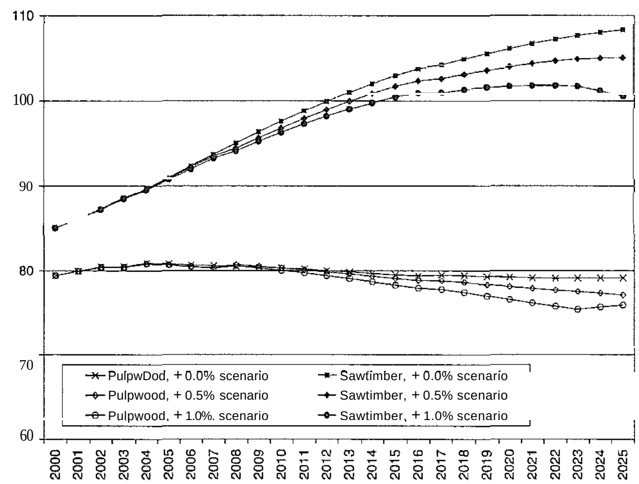

Figure 3. - Hardwood inventory projections for the 13-state southern region under three harvest increase scenarios, 2000 to 2025 (billion ft^3).

Figures 2 and 3 illustrate, respectively, softwood and hardwood inventory projections for the entire southern region under three removals scenarios. The projections are shown by product (pulpwood and sawtimber). Total softwood inventory is projected to increase 34, 24, and 15 percent under the 0, 0.5, and 1.0 percent scenarios, respectively, between 2000 and 2025 with pulpwood inventories peaking in 2004 and ultimately declining about 10 percent below their 2000 levels under all of the scenarios. Softwood sawtimber is generally expected to increase throughout the projection period. Under the 1.0 percent scenario, however, softwood sawtimber inventory trends downward during the last 4 years of the projection period. Total hardwood inventories are projected to increase 14, 11, and 7 percent under the 0, 0.5, and 1.0 percent scenarios. Pulpwood inventories are projected to remain approximately unchanged over the period under the constant removals level scenario and will decline about 3 and 4 percent under the 0.5 and 1.0 percent scenarios, respectively. Sawtimber inventories show net increases throughout the projection period, with the increases slowing down under the 0 and 0.5 percent sce-

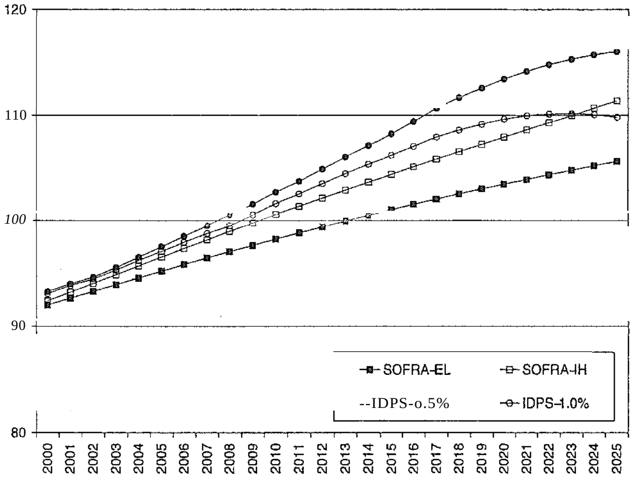

Figure 4. - Comparison of softwood inventory projections from SOFRA (IH and EL scenarios) and IOPS (0.5% and 1.0% scenarios) for the 13-state southern region, 2000 to 2025 (billion ft^3).

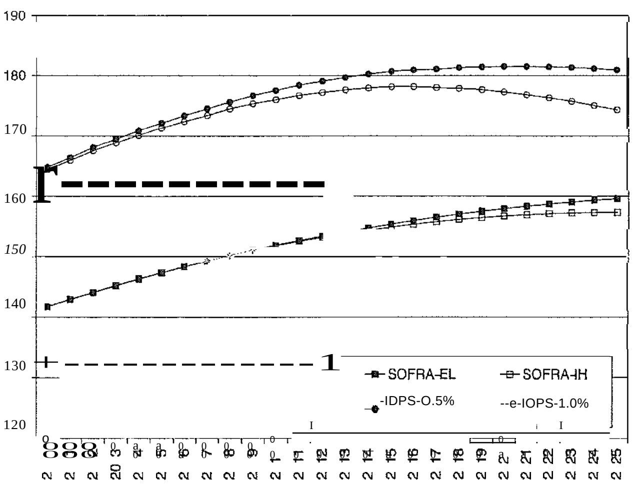

Figure 5. - Comparison of hardwood inventory projections from SOFRA (IH and EL scenarios) and IOPS (0.5% and 1.0% scenarios) for the 13-state southern region, 2000 to 2025 (billion ft^3).

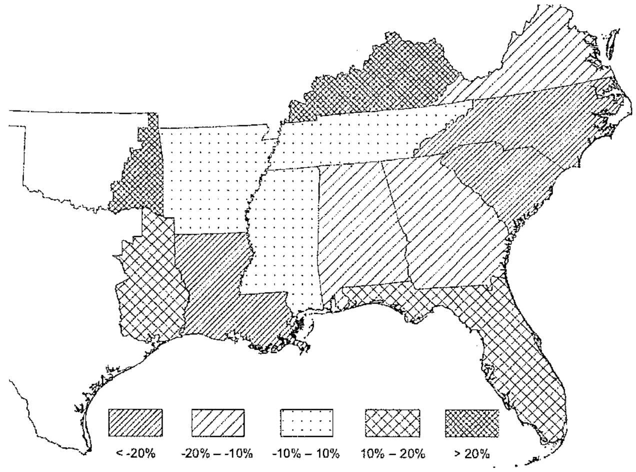

Figure 6. - Percentage changes in hardwood pulpwood inventory by state, 2000 to 2025, Base Scenario.

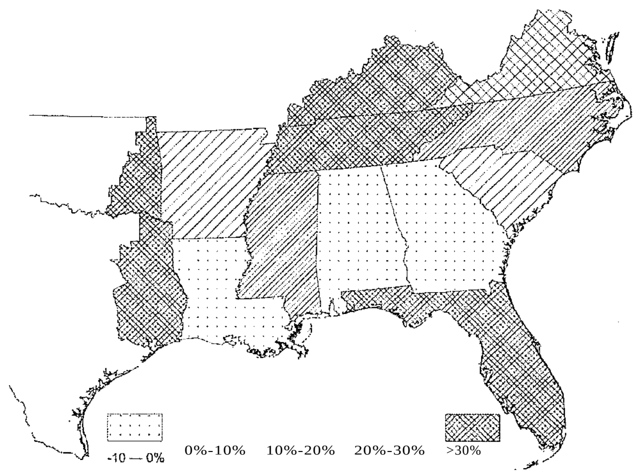

Figure 7. - Percentage changes in hardwood pulpwood harvest by state, 2000 to 2025, Base Scenario.

narios, and declining during the last 4 years of the projection period under the 1.0 percent increase in removals scenario.

Figures 4 and 5 present a comparison of softwood and hardwood inventory projections for the period 2000 to 2025 produced by two IDPS model scenarios (0.5% and 1.0%) and two SRTS model scenarios (EL and IH) used in the Southern Forest Resources Assessment (SOFRA). The most noticeable difference is initial hardwood inventories in the first year of the comparison period. The main reason for this difference is the fact that SRTS models the volume of growing stock while rDPS models the volume of live trees. Volume of live trees is 2 percent greater than volume of growing stock for softwoods, while for hardwoods, volume of live trees is 16 percent greater than volume of growing stock. Other reasons for the differences include IDPS inventory adjustments (from actual inventory year to the base year 2000) prior to projection, and the use of newer data for some of the states in the IDPS model.

Despite considerable differences in modeling approaches, the overall trends in development of aggregate softwood and hardwood inventories predicted by both models are remarkably similar. However, IDPS projections show slower increases in hardwood inventory while softwood inventory increases more slowly according to the SOFRA projections, despite adjustments made for future growth rates of pine plantations.

Interregional trade

A key feature of the model developed for this study revolves around acknowledging the role of interregional trade in meeting regional demand for roundwood products. As mentioned previously, in some states inventories dropped over the projection period followed by a decline in harvest levels (Figs. 6 and 7 for hardwood pulpwood) while overall harvest for the region increased over the projection period and met the increased demand levels for each state as they were represented by the scenarios. Trade among states allowed this to happen (Figs. 8 and 9). An example is the best way to illustrate how these

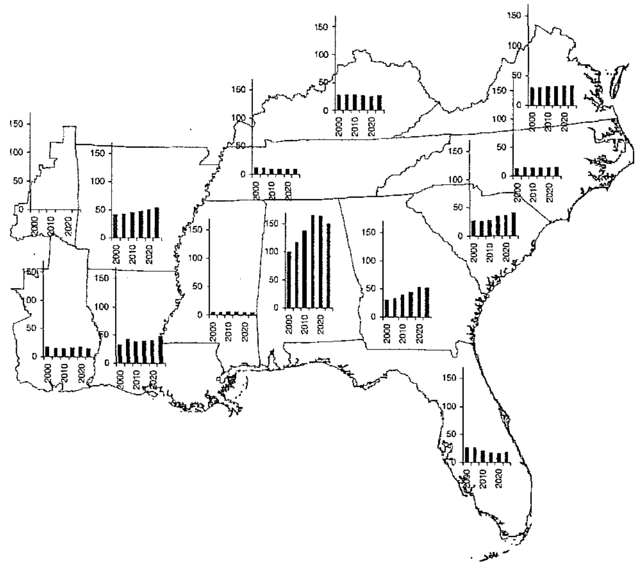

Figure 8. - Dynamics of hardwood pulpwood state-level imports, 2000 to 2025, Base Scenario (million ft^3).

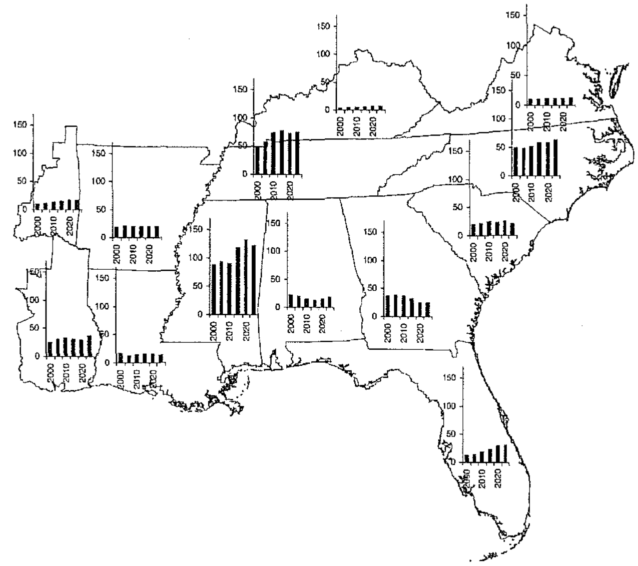

Figure 9. - Dynamics of hardwood pulpwood state-level exports, 2000 to 2025, Base Scenario (million ft^3).

effects interact in the simulation model. Consider Figures 7 and 8. Alabama and Louisiana are projected to reduce hardwood pulpwood harvest levels over the projection period (Fig. 7), while accommodating a 0.5 percent increase in demand (consumption) in the base case. In Figure 8, we see that this is accomplished by increasing imports of hardwood pulpwood in each state. No state that is projected to increase hardwood pulpwood harvest levels substantially is also projected to increase its imports of the product. A similar connection between Figure 7 and Figure 9 can also be made. As hardwood pulpwood harvest levels are projected to increase in several states (e.g., Florida, Mississippi, Tennessee, East Texas, Oklahoma, North Carolina), the exports of the product from those states will increase to help meet demands in other states.

Trade matrices are recalculated for each year of the simulation to account for changes in the relative ability of states to produce timber over and above the regional (state level) demand. For example, a state that has 100,000 acres available for harvest above those necessary to meet regional (state) demand would be relatively more likely to export to a state needing the product than another state that only has 50,000 acres available above its regional demand. Acres available means they meet the economic test of financial maturity. States with relatively more "surplus" available acres are more likely to be large exporters in a given period. States with a wider gap (deficit) between the amount of a product available for harvest and its regional demand will likely be relatively larger importers of the product in any given year. Distance is also a factor in establishing trading relationships with other states and that is evidenced in the trading tables. Most states trade with neighboring states and possibly one or two others. These trading relationships are important for understanding the dynamics of inventory growth and removals throughout the region and the ability of those relationships to help industries meet regional demands.

Inventory projections by state

Accounting for trade among states plays an important role in inventory projection on a state basis, where in some cases inventory dynamics are much different from the aggregated inventory dynamics of the 13-state region. In Virginia and North Carolina, significant declines in softwood pulpwood inventories are projected (-40% and -34%, respectively) for the base case. In North Carolina, hardwood pulpwood inventories are also projected to decline. In general, most states show large softwood sawtimber increases and are projected to have declining softwood pulpwood inventories under all scenarios. Hardwood pulpwood inventories are projected to decline 3 percent for the region under the base case, scenario, but a number of states including Alabama, Georgia, Lousiana, North Carolina, South Carolina, and Virginia show projected declines of 14 to 23 percent (mostly due to trees migrating from the pulpwood to sawtimber size class over the period). Reductions in harvest levels during the projection period have allowed inventories to remain stable in some states.

Table 1 presents a comparison of softwood and hardwood inventory dynamics by state projected by the base case scenario of IDPS (0.5% removals increase) with the base case scenario of SOFRA (inelastic demand, high plantations growth rate increase). We aggregated volumes of pulpwood and sawtimber produced by IDPS in order to be able to make comparisons with the SOFRA projections. In most cases, inventory changes are in the same direction while magnitudes differ, sometimes significantly. The results for softwood in Oklahoma are strikingly dissimilar, but this is likely a consequence of this region's very small size as a roundwood producer and consumer.

Other differences in the projections are likely a function of different approaches to growth and harvest modeling (on the stand basis in IDPS vs. aggregated in SOFRA), different starting inventory and removals levels, and accounting for or ignoring the interregional trade of roundwood products. To illustrate this, we will compare dynamics of softwood inventory and removals projected by base case scenarios of IDPS and SOFRA for Mississippi and Alabama (Figs. 10 and 11). Starting inventory for Alabama differs between IDPS and SOFRA because IDPS uses newer FIA data (2000). Starting inventory in Mississippi is lower according to IDPS because

Table 1. - *Dynamics of softwood and hardwood inventory projections from fOPS 0.5 percent scenario and SOFRA IH scenario for* 13 *southern states, 2000 to 2025.*

	Softwoods		Hardwoods	
State	mrs 0.5%	SOFRAIH	mrs 0.5%	SOFRAIH
	-------------------------	(%)	----------------------	
AL	23.4	20.4	7.6	18.0
AR	26.0	46.4	23.0	5.5
FL	79.0	46.2	30.0	11.5
GA	35.2	4.7	3.8	-3.5
KY	82.3	74.5	35.9	53.1
LA	-8.3	-4.3	-8.9	10.9
MS	40.2	12.3	-0.7	-9.9
NC	2.1	18.8	-12.6	-0.9
OK	-12.8	87.5	83.8	57.3
SC	20.7	11.0	-2.6	-10.8
TN	15.4	35.8	22.8	20.0
TX	6.8	9.7	22.6	6.1
VA	33.5	26.0	4.2	7.0
Total	24.5	20.5	10.8	11.0

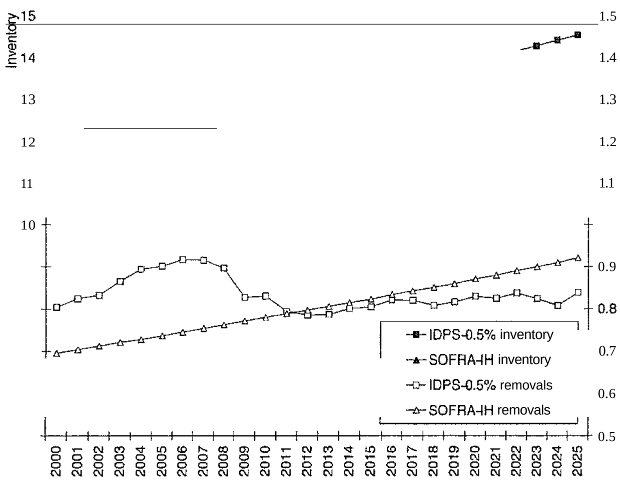

Figure 10. - Comparison of softwood inventory and removals projections from SOFRA IH scenario and lOPS 0.5 percent scenario for Alabama, 2000 to 2025 (billion ft^3*).*

of inventory adjustments, where IDPS was "growing" inventory and "harvesting" known removals during the period 1994 to 2000, and in SOFRA it was determined after 5 years of model projections (1995 to 2000). The removals levels are different because IDPS used newer TPO/Southem pulpwood production data.

In both cases, the SOFRA projections show increases for inventory and removals at almost a constant rate in both states during the period of comparison. At the beginning of this period, IDPS shows declining softwood inventory in Mississippi because of higher harvest rates during the inventory adjustment period 1994 to 2000. The associated decline in inventory, and in particular of the inventory available for harvesting, caused Mississippi softwood roundwood demand to be reallocated by the interregional trade model to the states with a high propensity to trade with Mississippi and where softwood inventory available for harvesting was not in short sup-

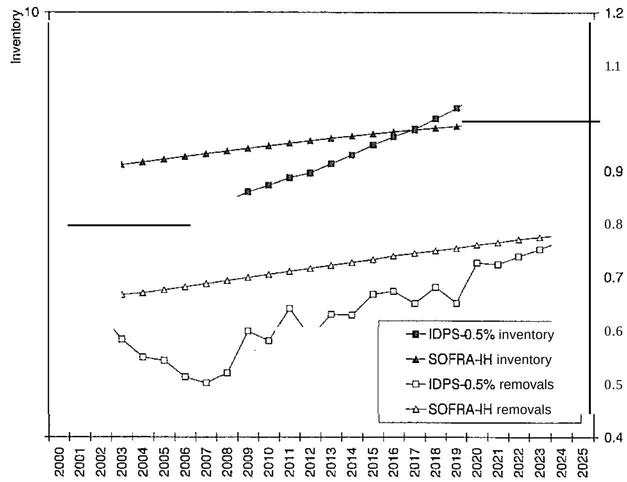

Figure 11. - *Comparison of softwood inventory and removals projections from SOFRA IH scenario and lOPS 0.5 percent scenario for Mississippi, 2000 to 2025 (billion* ft^3*).*

ply, in particular, Alabama. In Alabama, we observe a relatively higher rate of inventory increase in the beginning of the projection period. As reallocation of removals takes place, removals decline in Mississippi and increase in Alabama (at a rate higher than the rate of increase of Alabama roundwood demand, which is 0.5 percent a year in this scenario).

At the same time, Alabama's net import declines, Mississippi's net import increases, and net trade from Alabama to Mississippi increases (Fig. 12). As a result, Mississippi's inventory recovers and Alabama's inventory growth slows down. The trade quantities return to near their initial levels, and inventory continues to increase at more stable rates. Alabama's net export decreases in the end of the period due to the relatively greater inventory increase in Georgia and Florida, which are the other two states having significant trade of softwood roundwood with Alabama. As we can see from this example, the ability of the model to reallocate roundwood demand is an important factor in overcoming bottlenecks in inventory or age structure dynamics, which allows recovery after inventory declines without jeopardizing local demand. However, this model allows reallocating roundwood demand only to those regions that have higher propensity to trade with the state in question as reflected in the matrix of trade coefficients. As a result, only those regions are affected by the inventory dynamics of the region in question. For example, the decline of Alabama's softwood inventory in 2004 to 2009 was caused by a sh011age of softwood available for harvest in Mississippi in 2000 to 2004, while states with low propensity to trade with Mississippi, like Kentucky or Virginia, were not affected.

Conclusions

IDPS is an interregional multiproduct timber inventory projection system, which models growth at the stand level, uses a net present value maximization framework to model optimal harvesting decisions, and a gravity model for interregional trade. It provides a framework for analyzing timber supply on regional and/or state levels.

The system was used to project timber inventories in 13 southern states through 2025. The projections show a 24 percent increase in softwood inventory and 9 percent increase in

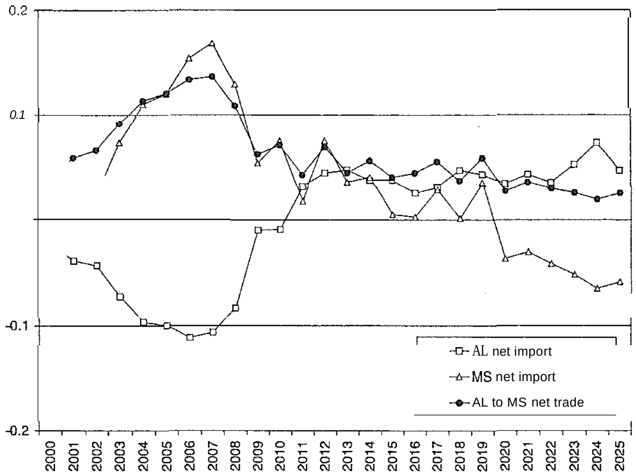

Figure 12. - Softwood roundwood trade for Alabama and Mississippi according to projections of IDPS 0.5 percent scenario, 2000 to 2025 (billion ft³).

hardwood inventory given a base case scenario of 0.5 percent annual increase in consumption. However, the pulpwood component of total inventory is predicted to decline approximately 10 percent for softwood and 3 to 4 percent for hardwood over the 25-year projection period.

The IDPS model treats subregions (states) as interconnected markets. It recognizes the mutual influence of states as supply and demand regions. It could also be used to analyze regional demand or supply shocks such as new mill construction or mill closures, urbanization, or natural disasters.

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