Alternative Projections of the Impacts of Private Investment on Southern Forests: A Comparison of Two Large-Scale Forest Sector Models of the United States

Ralph Alig, Darius Adams, John Mills, Richard Haynes, Peter Ince and Robert Moulton

Alig, R., Adams, D., Mills, J., Haynes, R., Ince, P. & Moulton, R. 2001. Alternative projections of the impacts of private investment on southern forests: a comparison of two large-scale forest sector models of the United States. Silva Fennica 35(3): 265–276.

The TAMM/NAPAP/ATLAS/AREACHANGE (TNAA) system and the Forest and Agriculture Sector Optimization Model (FASOM) are two large-scale forestry sector modeling systems that have been employed to analyze the U.S. forest resource situation. The TNAA system of static, spatial equilibrium models has been applied to make 50-year projections of the U.S. forest sector for more than 20 years. Much of its input on forest management behavior and decisions about use of forestland derives from expert-based systems external to the TNAA system. FASOM, a spatial intertemporal optimization model, directly incorporates decisions on management investment and land use options relative to agricultural alternatives as endogenous model elements. The paper contrasts projections of private forest investment from the TNAA and FASOM models, focusing on the southern United States. Comparison of the TNAA base case and an investment-restricted scenario from FASOM, both of which reflect a continuation of recent behavioral tendencies by nonindustrial private owners, suggests that Southern private timberlands have considerable biological and economic potential for intensified forest management. Unrestricted FASOM projections confirm that added investment could lead to substantially larger timber harvest volumes and lower prices than those projected in the base/restricted cases. But even under the more intensive investment scenarios, naturally regenerated forests would cover three-quarters of the future private timberland base and hardwoods would continue to dominate the inventory structure.

Keywords timber supply, forest sector, forest resource assessment, plantation area
Authors' addresses *Alig*, USDA Forest Service, Forestry Sciences Lab, 3200 SW Jefferson Way, Corvallis, Oregon 97331 USA; *Adams*, College of Forestry, Oregon State University, Corvallis, Oregon, 97331 USA; *Mills* and *Haynes*, USDA Forest Service, Forestry Sciences Lab, 1221 SW Yamhill, Portland, Oregon 97205, USA; *Ince*, USDA Forest Service; Forest Products Lab, Madison, Wisconsin, 53705 USA; *Moulton*, USDA Forest Service (retired); Research Triangle Park, North Carolina, 27709, USA.
Fax (Alig) 541 750 7329 **E-mail** ralig@fs.fed.us
Received 3 February 2001 **Accepted** 14 May 2001

1 Introduction

With increasing demands for wood products and a smaller share of harvest coming from public lands in the United States, some analysts look to private timberlands to provide more profitable timber production in an environmentally responsible manner. Private timberland in the United States comprises 145 million hectares and supplies the largest part of the country's wood requirements (Powell et al. 1993). Despite increased substitution of nonwood products for wood and slower economic and population growth, the long-term demand for wood products is not expected to decline (Haynes et al. 1995). U.S. population will continue to grow, particularly in the southern and western regions, with a projected increase of more than 120 million people by 2050. Increases in population and income will, in turn, increase demands for land for residential, infrastructural and other uses and conversion of forest land to nonforest or nontimber uses is likely to continue (e.g., Mauldin et al. 1999). As a consequence, while private timberlands will become increasingly important in the nation's timber supply their area will decline, and there will be growing incentive to expand long-term growth and harvest from these lands through investment.

Large-scale forest sector modeling systems for analyzing scenarios about the future U.S. private timber resource situation include: (i) a network of models developed for the USDA Forest Service's Timber Assessment reports, the TNAA (TAMM/ATLAS/NAPAP/AREACHANGE) system[1] and (ii) the FASOM (Forest and Agriculture Sector Optimization Model) model developed jointly by the U.S. Environmental Protection Agency and USDA Forest Service to examine forest and agricultural carbon sequestration policies (Adams et al. 1996a). Both models explicitly consider the extent and structure of the private timber resource in some detail but employ markedly different schemes for modeling private timber investment and management behavior. The purpose of this paper is to contrast projections of the extent and impacts of future private forest investment derived from the two model systems, with particular attention to the southern region of the United States. We first provide a summary of trends and recent developments in private forest management as background for the modeling analysis. Subsequent sections describe the model systems and apply them to analyze private forest investment scenarios under different assumptions about the cost of capital and forms of private owner behavior. A final section considers the advantages and limitations of the two approaches and options for synergistic applications.

[1] Current documentation for the TNAA model, Resources Planning Act (RPA) Assessments, and reports of the most recent projections can be found at http://www.fs.fed.us/pnw/sev/rpa/index.htm

2 Trends in Private Forest Investment and Management

Changing forest product market and policy conditions in recent years have been associated with marked intensification of timber management on some private lands in the United States and with an increasing share of total harvest being derived from private lands. Between 1986 and 1996, the share of U.S. softwood timber harvests from public forests dropped by more than half, from 26 to 12%. In the wake of these shifts, rising timber prices induced investment to enhance timber yields, primarily through the use of planting stock.

The major U.S. forest regions have widely different potentials to attract private investments in forest production. Rapid tree growth generally translates into higher potential economic returns to investors, and tree growth is fastest in the South and wetter areas of the Pacific Northwest. The present paper focuses on the South that accounts for about 80% of U.S. tree planting, has large areas of marginal agricultural land that could be planted to trees, and is near to major wood-processing facilities that are relatively close to the large concentration of the population in the East.

2.1 Trends in U.S. Planted Forest Area

Despite major historical transfers of land to agriculture, the United States still has a very large forested area – 302 million ha – roughly 75% of the original forest area. Since 1952 the area of U.S. forestland has declined about 4%, with the largest net losses being to developed uses (Alig and Wear 1992). The planting of trees to create forest plantations has emerged as a major activity in recent decades. However, it is worth noting that plantations occupy only about 16 million ha, 5% of U.S. forestland area and 8% of the timberland area, while naturally regenerated stands occur on the remainder.

Expansion of plantation area in the United States is consistent with broad trends in other key timber growing regions of the world, where plantations increasingly are the source of industrial wood. Plantations in many cases offer timber supply advantages in terms of location, accessibility, operability, wood type, and wood quality. The vast majority of tree planting on private timberland consists of softwood species, mainly because softwoods have long fibers that are desirable in papermaking and they produce larger volumes of higher value sawtimber in less time, relative to hardwoods.

U.S. tree planting is concentrated in the 13-state South (about 80% of the U.S. total), as compared with 16% in the West and 4% in the North (e.g., Moulton 1999). In 1998, 10 states – in the South – each planted more than 40 thousand ha, and collectively planted 820 thousand ha in 1998, 77% of the U.S. total.

The South is the leading tree planting area in the United States for a number of reasons, including a favorable climate (long growing season and generally abundant precipitation), excellent markets for wood due to the heavy concentration of forest industry in the region, and comparatively less competition for land from agriculture. The South does have an important and diversified agricultural sector, but it is based on fruits and vegetables (citrus, onions, peaches, and other truck crops), rice, tobacco, cotton, poultry, hogs, and other meats. The South is not a significant producer of major field crops like corn and wheat.

The South also enjoys a cost advantage in that southern pine seedlings (e.g., loblolly and slash pine) need only be grown in nurseries for one year before they are ready for field planting. Currently, high quality, genetically improved southern pines are available in the South for about US$35 per thousand seedlings. In contrast, conifer seedlings in the North (white pine, red pine and spruces) and West (Douglas-fir, ponderosa pine) cost US$150–300 per thousand, as they must be grown for two to three years, and may have to be transplanted within the nursery.

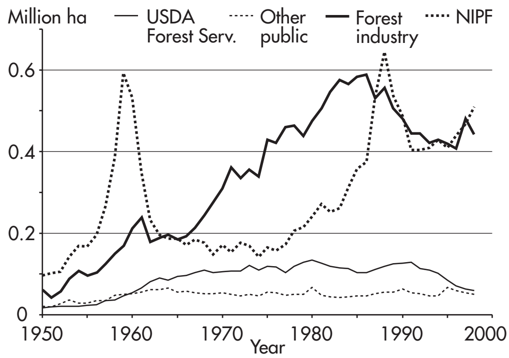

Fig. 1. Tree planting in the United States by forest ownership, 1950–1998.

The U.S. South is a key supplier of fiber for papermaking and contains about two-thirds of the fast-growing coniferous plantations in the world, equal in 1997 to about 12 million ha of southern pine plantations. The South contains two-thirds of the U.S. plantation area (Brooks 1993), with planted pine area in the South increasing more than 10-fold since 1952 (USDA Forest Service 1988). Within the South, a proportionately larger amount of forest industry (FI) timberland (32%) is planted compared to nonindustrial private forest (NIPF) timberland (6%), with about 12% of the total southern timberland covered by plantations. Overall, a large majority of U.S. tree planting is by private land owners (Fig. 1).

2.2 Past Studies of Investment Opportunities

A number of regional and national studies have examined and inventoried the area of private timberland on which timber management could be intensified in the United States (see, as examples, USDA Forest Service 1973, 1988, 1990). These studies have identified large areas of private timberland with biological potential for increased net growth through more intensive forest management. Using static investment analyses with fixed prices, the studies suggest as well that substantial portions of these investments could provide an attractive financial return (USDA Forest Service 1990, Alig and Wear 1992). Past analysis has also consistently shown a large potential for intensification on NIPF lands and to a lesser extent on forest industry ownerships. For example, in the 1989 Resources Planning Act Timber Assessment by the USDA Forest Service (1990), more than 24 million ha of NIPF land were identified as having potential for increased growth through intensified management, while returning a real rate of return of at least 4%. These opportunities are concentrated in the South and include more than 8 million hectares of timberland that offer attractive rates of return if regenerated to plantations. If these investments were undertaken and sustained, they would result in a timber volume increment of some 20 million cubic meters at harvest.

3 Alternative Forest Sector Modeling Systems

The following discussion outlines the structure and application of the TNAA and FASOM models with particular attention to their dissimilar treatment of private harvest, management, and investment decisions.

3.1 The TNAA System

The TNAA system is comprised of four linked models originally developed for independent (partial) analysis of specific sectors: the Timber Assessment Market Model (TAMM) covers solid wood products and provides an interface with the timber resource; the North American Pulp and Paper (NAPAP) model treats pulp, paper, and paperboard products and associated supplies of recycled fiber, residues, and pulpwood; the Aggregate TimberLand Assessment System (ATLAS) projects the timber inventory and provides a vehicle for modeling management investment; and the AREACHANGE model projects the shifting of timberland between forest and nonforest uses and among forest cover types.

TAMM is a static, price endogenous, spatial equilibrium model. Market solutions are obtained one period at a time using direct optimization of the nonlinear market surplus objective function. TAMM projects prices, consumption, and production of softwood and hardwood sawtimber products, and harvest of sawtimber from private lands and associated timber prices. In the TNAA system, TAMM also serves as the interface with the timber inventory module (ATLAS), combining harvest projections for all products and passing back inventory and other resource measures as needed. A detailed discussion of TAMM can be found in Adams and Haynes (1996).

Consumption, production, prices, and trade in pulp, paper, paperboard, and fiber markets are projected by the NAPAP model. Similar to TAMM, NAPAP is a static, price endogenous, spatial equilibrium model of the pulp and paper sector in North America. The NAPAP pulpwood market equilibria include pulpwood used in OSB and other wood panel products (as determined by TAMM). Ince (1998) and Zhang et al. (1993, 1996) provide descriptions of NAPAP and its supporting software.

Timber inventories *on private ownerships only* are projected using a modified version of the ATLAS model (Mills and Kincaid 1992). Timberland is stratified by region, owner, (representative) age class, site productivity group, management intensity class, and forest type. A management intensity class is defined by the regime of silvicultural practices applied to a land unit. In the case of even-aged management it includes, as a partial list, actions such as regeneration method, type of planting stock, precommercial and commercial thinning, and fertilization. These actions are depicted in ATLAS through the use of a specific age-dependent yield function for each even-aged stratum (or yield process for partial cutting) that reflects the growth and yield impacts of the regime. Lands classified under even-aged management can shift among management intensity classes over time to reflect changes in timber management investment.

The extent and timing of management shifts are determined outside of the ATLAS model and occur only after harvest. Both the initial distribution of area by management intensity class and the shifts of areas between classes over time are established in the TNAA system by reference to panels of experts from industry and public agencies (e.g., USDA Forest Service 1990: Chapter 9). Convened on a regional basis, these groups translate estimates of current actual management practices (derived in some cases by surveys of owners) into the management intensity categories used in ATLAS to give the current management distribution. They also develop scenarios of future trends in management practices by owner group. For example, they estimate the level of management intensity for pine plantations in the South, with respect to whether precommercial thinning, fertilization, commercial thinning, and other intermediate practices are applied. These provide bases for MIC shifting in ATLAS but one limitation is the lack of a common set of background assumptions by the panels on future price trends and other conditions that might influence management decisions.

Over time the AREACHANGE model adjusts the timberland base used in ATLAS for movement of land between forest (e.g., timber production) and non-forest (including, agricultural, urban and reserved) uses and among forest types. Projections of these shifts are developed based on regional models of area changes. A projection by AREACHANGE operates in two phases. In the first phase, area changes in major land uses are projected to provide regional estimates of total timberland area by ownership. In the second phase, the system projects area changes for major forest types on each ownership. Price projections from other parts of the Timber Assessment modeling system are used as one of the inputs in the first phase of the projections, and projections of management intensity class changes from the ATLAS model are used as an input in the second phase (Alig and Wear 1992).

3.2 FASOM

FASOM is a linked model of the U.S. forest and agriculture sectors (Adams et al 1996a, Alig et al. 1998). It employs a joint objective function, maximizing the present value of producers' and consumers' surpluses in the markets of the two sectors subject to restrictions on the disposition of the land base that is suitable for use in either sector. The structure is an optimizing intertemporal spatial equilibrium market model that simulates prices, production, consumption, and management actions in the two sectors. Simulations proceed on a decade time step with a nine decade time horizon to accommodate treatment of terminal inventories. As in all such models, consumers and producers are assumed to have full knowledge of current and future market conditions and access to perfect markets for capital.

Treatment of the forest sector is restricted to the market for logs, which are distinguished by species (hardwood and softwood) and product (sawlogs, pulpwood, and fuelwood). Demand functions for logs were derived from solutions of the TAMM and NAPAP models (as described above). The resulting functions shift over the decades of the projection. They incorporate endogenous adjustments and substitution responses in the TAMM and NAPAP models, as would be observed in a 10 year period, and are more elastic than the short-run relations found in TAMM and NAPAP. Log processing capacity is limited in each time period and decisions to purchase additional capacity are treated as endogenous. Output in certain product categories can be used as substitutes (sawlogs for pulpwood, pulpwood for fuelwood) and residue generated in sawlog processing can replace pulpwood. Export demand and import supply relations are used to represent options for log trade with other countries. The agricultural sector model was expanded and adapted from an earlier equilibrium model described by Chang et al. (1992).

Similar to ATLAS, private timber inventories are modeled using the "linear forest" structure described by Johansson and Löfgren (1985) [or the "model II" form of Johnson and Scheurman (1977)]. Timberland is differentiated by age class, forest type, management intensity class, suitability for agriculture, and site quality, for nine domestic regions and two ownerships (industrial and nonindustrial). Harvest age, management intensity class, and forest type decisions (when regenerating harvested land) are endogenous. Log supply from public lands is fixed.

The land bases for agriculture and forestry are linked. Land use decisions on industrial ownerships are treated as exogenous, but a portion of nonindustrial land is suitable for both uses and may move between the sectors as land rents dictate. Thus, land available for forestry can vary over time depending on the relative net benefits (market surpluses) of its use in agriculture or forestry. Unlike in the TNAA system, FASOM's land use pattern is endogenous and established for all periods simultaneously with values for other endogenous variables.

Management intensity classes (MICs) in FASOM are defined analogously to those in ATLAS, as distinct combinations of silvicultural practices. FASOM uses a smaller set of MICs than does ATLAS (4 versus 5–11 in ATLAS), though the range of intensities is similar: passive – no management intervention of any kind between harvests of naturally regenerated aggregates; low – custodial management of naturally regenerated aggregates; medium – minimal management in planted aggregates; and high – genetically improved stock, fertilization or other intermediate stand treatments in planted aggregates. Specific practices differ by region, site quality, and forest type. Growth of existing and regenerated stands is simulated by means of timber yield tables that give the net growing stock volume per ha in unharvested stands by age class for each stratum, just as in ATLAS. FASOM associates a cost with each MIC that includes both establishment and growing (e.g., fertilization) activities. Costs differ by region, species, and timber management practice.

MIC is assigned at the outset of the projection for stands in the initial inventory and reassigned each time a stand is regenerated. FASOM associates a cost per unit area, incurred at the time of stand regeneration, with each MIC. During the model solution process, optimal harvesting timing and subsequent regeneration MICs (including forest type) are endogenous (in contrast to ATLAS) and chosen for all stands over the full projection. In the FASOM objective function, the trade-offs in this selection are between the potential yields (and ultimately the producer and consumer surpluses generated) and the costs of each MIC.

4 Projections of Private Investment with TNAA and FASOM

To illustrate the differences between the TNAA and FASOM modeling approaches, we used the two models to develop alternative projections of future management investments on U.S. private timberlands and how these will affect timber supply. We focus on the South, the region with greatest private forest investment activity. For each scenario, we show projections of plantation area for forest industry and nonindustrial private owners, timber management intensity, timber inventory levels, and log prices.

An initial comparison is made between the "base" projections of the models. The assumptions for demand and other market conditions are the same for both models and derive from the USDA Forest Service's 1993 RPA Update (Haynes et al. 1995). In the TNAA model management investment shifts are derived from external sources, as described above. They are not sensitive to price or other changes during the course of the projection, and for nonindustrial owners involve little departure from past trends and levels of practice. In FASOM, however, future investments are presumed to be made in an economically rationale process to maximize present value of future net returns, assuming a perfect capital market (no limit on borrowing or lending) and a constant interest rate of 4% (in the base case). Although perfect capital markets do not imply unlimited investment, it is clear that this approach will give a fundamentally different view of future management practices than will the TNAA model.

To examine FASOM's sensitivity to changes in these critical investment conditions, we modified two elements in its investment calculus, access to borrowing and the discount rate, in three scenarios: 1) restricted availability of capital for NIPF owners for use in tree planting investments to the average levels observed in the late 1990s in the U.S. South; 2) a lower discount rate at 2%; and 3) a higher discount rate at 10%. It is generally recognized that NIPF owners do operate under actual or perceived credit rationing, and borrowing limits have been examined in other contexts (see, for example, Kuuluvainen and

Salo 1991) though not specifically with regard to investment in management. There is also considerable uncertainty regarding the discount rate appropriate for private owners. The wide range employed here examines the extremes of the likely range of rates.

4.1 Comparison of Base Projections

4.1.1 Plantation area

Table 1 shows the TNAA and FASOM base projections of southern private plantation areas from 1990 to 2030. In the TNAA base case, about 9.0 million hectares of forest plantations are added in the South, in contrast to 28.0 million hectares projected by the FASOM model. Almost all the area difference between the two baseline projections is associated with the NIPF ownership.

Potential increments in private plantation area are consistent with investment opportunities identified in earlier studies (e.g., Alig and Wear 1992). When FASOM base case projections of planted areas are compared to the TNAA projections, results differed more in degree than in form. This may reflect, in part, consideration of data on "economic opportunities" for silvicultural investments by management experts in the TNAA system as they developed their intensity shifting assumptions (Haynes et al. 1995). The tendency would be to assume more area moving to higher management intensity classes in regions and ownerships where such opportunities are abundant (see, for example, USDA Forest Service 1990: Chapter 9). Under the perfect capital markets assumption, the FASOM model selects much higher levels (larger areas) of plantation investment.

Table 1. TAMM and FASOM projections of plantation areas on private timberland in the South, for the base case and three scenarios, 1990–2040 (million ha).

Owner/ start of decade	TAMM Base	FASOM Base	FASOM Restricted	FASOM 2%	FASOM 10%
			Million hectares		
FI					
1990	5.267	5.267	5.267	5.267	5.267
2000	8.345	7.042	12.378	8.132	6.225
2030	10.176	10.171	14.224	9.234	9.028
NIPF					
1990	4.051	4.051	4.051	4.051	4.051
2000	6.301	15.551	6.529	19.534	13.274
2030	8.167	27.936	6.452	28.076	27.808

Projected plantation activity includes conversion of substantial areas of hardwood types to softwoods in the South. Type conversion in the first several decades is fueled by a relative shortage in softwoods. This contributes in turn to declining hardwood harvest volumes and rising hardwood prices in later periods (beginning about 2020).

Although plantation areas expand markedly in the FASOM base case relative to current levels, future private forests would still be predominantly of natural origin. By 2030, U.S. private timberland would be comprised, at a maximum, of about one quarter of softwood plantations, with a somewhat higher proportion in the South. About four-fifths of the NIPF timberland area would still be concentrated in the lower management intensity classes that involve naturally regenerated stands, in contrast to about one-half for forest industry. This is significant since the growing area of plantations effectively reduces pressure on naturally regenerated forests as a source of industrial wood.

4.1.2 Intensity of Plantation Management

The initial (1990) distribution of FI and NIPF pine plantation area by two groups of timber management intensity classes has the most area in the lowest intensity level of plantation management ("medium" group): 60% for FI and 86% for NIPF owners, for both TNAA and FASOM. The remainders are in the "hi" group of management intensity classes that involve higher levels of investment, e.g., precommercial thinning, fertilization, and commercial thinning. Thus, FI currently has a higher proportion of relatively intensive plantation management.

The FASOM base case projection places almost all the pine plantations in the "medium" group by 2030, while the TNAA system projects a significant share of plantations to be in the "hi" group. This difference is due to the FASOM model projecting a higher short-term level of investment in establishing pine plantations (Table 1), thus later reducing the incentives to shift plantations into the highest management intensity classes. The large area of plantations in the first two decades, relative to the TNAA-based projections, results in a larger subsequent timber supply, with lower timber prices.

Large future investments in plantation establishment relative to historical levels in either model would not mean that the bulk of private lands will be more intensively managed than at present. Indeed, averaged over all private lands, most plantations would receive less intensive treatments. Scarce investment dollars are allocated to the most productive lands that receive a significant increase in management intensity. Other areas receive less investment. In FASOM, for example, some naturally-regenerated lands in the low management intensity class are shifted into the lowest (passive) class.

4.1.3 Price and Harvest Projections

Given the investment activity described above, harvests in the FASOM base projection can expand readily to meet growing demand and softwood pulpwood prices change little over the course of the projection. In contrast to TNAA that uses fixed investment schedules and a market model with only a single period's horizon, the FASOM base projection of softwood pulpwood prices is far less volatile and exhibits little growth. Within FASOM's highly flexible structure, private timber producers can anticipate future price movements and plan current investment and harvest accordingly.

Base timber harvest rises for both softwoods and hardwoods over the full projection. The FASOM base case projections have larger softwood pulpwood harvests in all decades than the base projection with the TNAA models, while softwood pulpwood prices are lower. This same general relationship holds for sawtimber projections and hardwood projections as well. In the FASOM model, unrestricted management investment allows larger harvests in all periods, including the 1990 and 2000 decades in anticipation of future growth increases.

The importance of investments in pine plantations to future timber supplies is indicated by the changes over time in share of timber harvest from plantations. The share is projected to grow substantially, especially in the South. Pine plantations in the South supplied about 10% of total harvest in 1990 and that is projected by the TNAA models to grow to 48% by 2030. The largest increase is for forest industry timberlands, where the percentage increases from 20 to 87%, compared to an increase from 6 to 28% on NIPF timberland.

4.2 Scenarios Using FASOM

FASOM's model of private investment decisions presumes that owners pursue, in effect, an objective of land value maximization, limited only by conditions of the market (e.g., interest rates) and of their initial inventories of land and timber. There are, of course, many conditions that act to restrict investment behavior. In the first alternative scenario, we examined one class of constraints – availability of investable funds – limiting NIPF investment expenditures to levels observed in the recent past. In this *Limited NIPF Investment* scenario, we restricted future annual expenditures for NIPF tree planting investments to the level observed in 1993 (Mangold et al. 1995). The constraints were imposed by region. We would expect that limited or constrained NIPF capacity to invest will lead to higher log prices, less plantation area on NIPF lands in the South, and increased forest investment by forest industry owners.

In the other two alternative scenarios, we tested the impacts from using a 2% (*2% Interest Rate*) and 10% (*10% Interest Rate*) interest rate, respectively, in contrast to the 4% rate in the base case. We expect that a lower interest rate would result in more tree planting by both private owner groups in the South, and conversely with the higher interest rate scenario. The higher interest rate may also lead to more timber harvest in the near term relative to the base case, as owners shorten timber rotations in response to higher costs of capital.

4.2.1 Plantation Area

Projected areas of planted private timberland differed notably among the three alternative scenarios and in comparison to the base case (Table 1). Constraining the level of plantation investment under the *Limited NIPF Investment* scenario substantially lowers NIPF plantation area in the South. The increment of NIPF plantation area added during the first projection decade under the *Limited NIPF Investment* scenario is less than one-quarter of that in the base case (and close to the TNAA projection). This pattern on NIPF lands holds over the projection period, where the 2030 NIPF plantation area is only about one-fourth that of the BASE level.

The interrelation of private owner decision making in response to market signals is illustrated here by industry's response under the *Limited NIPF Investment* scenario. Industry is projected to add more than four times the pine plantation area in the first projection decade compared to the increment in the base case. By 2030, industry's total plantation area would be 40% higher than in the base.

Area changes under the two interest rate scenarios are not as large, relative to changes under the limited NIPF investment scenario. Under the *2% Interest Rate* scenario, the increment of private plantation area for the first projection decade would be 38% higher compared to the base case (with a 4% discount rate) (table 1). Conversely, under the *10% Interest Rate* scenario, the increment of plantation area during the first projection decade would be 30% smaller than the base level due to higher costs of capital.

4.2.2 Intensity of Plantation Management

The projected distribution of planted FI and NIPF timberland area by medium and high management intensity classes is also affected by NIPF investment constraints. Industry owners are projected by the FASOM model to apply a higher proportion of intensive plantation management (e.g., precommercial thinning, fertilization, and commercial thinning) relative to the BASE. Industry owners are projected to apply a higher proportion of intensive plantation management under the *2% Interest Rate* scenario, but there would be less expenditure for intensive plantation management under the *10% Interest Rate* scenario.

4.2.3 Price and Harvest Projections

Given the investment activity described above for the *Limited NIPF Investment* scenario, projected softwood pulpwood harvests in the longer-term (2030) would be reduced by 20% and softwood pulpwood prices would be 66% higher than BASE levels (Fig. 2). Private timber producers anticipate future price movements associated with less longer-term supply from significantly less investment under the *Limited NIPF Investment* scenario. They plan near-term harvest accordingly. Prices would rise with more rapid depletion of initial timber stocks in the first decade of the scenario.

Under the *2% Interest Rate* scenario, softwood pulpwood harvest initially rises and then falls compared to FASOM BASE levels (Fig. 2). More

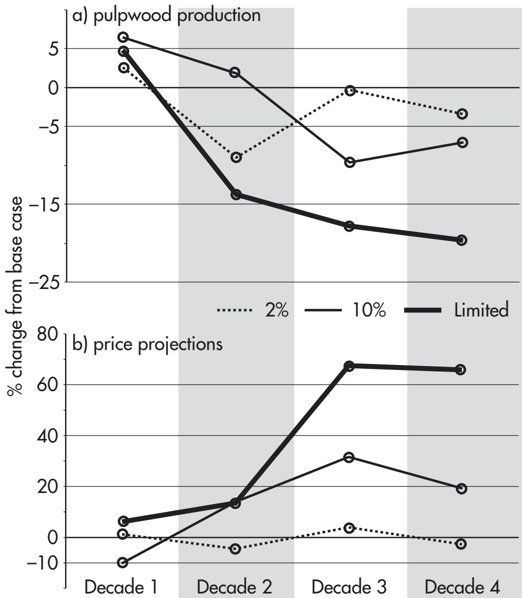

Fig. 2. Projections of softwood pulpwood production (a) and prices (b) with the FASOM model, with percentage changes relative to the FASOM base case for the three alternative scenarios.

investment by both private owner groups initially produces higher softwood harvests than the base projection, while softwood pulpwood prices fluctuate around the base levels. Conversely, under the *10% Interest Rate* scenario, reduced management investment compared to the BASE leads to a larger reduction in harvest levels and higher timber prices.

The share of timber harvest from plantations is projected to be larger under the *2% Interest Rate* scenario. With more plantation investment by both owner groups in response to lower interest rates, this would further reduce pressure on naturally regenerated forests as timber production is concentrated on fewer but more intensively managed hectares.

5 Discussion and Conclusions

Private forest investment is a critical element in the long-term modeling of U.S. forest resources. Development of the FASOM model depended in part on the TNAA system and complements the TNAA models for analyses of private forest investments that are linked to harvest and price modeling. Base case projections with the FASOM model have intertemporal investment decisions linked to harvest timing and suggest that U.S. private timberlands have considerable potential for sustainable wood production under intensified management. Indeed, forest investment at levels projected by FASOM's optimization approach could lead to substantially greater timber harvest volumes and lower prices than those in the TNAA base case (as presented in Haynes et al. 1995). Under FASOM's assumptions of perfect foresight and perfect capital markets, harvest could potentially expand to meet growing demand such that softwood log prices would vary little over the projection. The requisite levels of aggregate private investment would, however, be well beyond those observed in recent years. The 2030 area in planted forests in the South would almost be double that in the TNAA base case.

Private harvest in the United States over the next two decades will be strongly influenced by current timber inventory characteristics, particularly the limited areas and timber volumes in older merchantable age classes in virtually all regions. Despite these conditions, FASOM projections indicated that expanded investment would allow some immediate increments in timber harvest, sustained increases in timber inventory, and virtually no long-term trend in softwood log prices. In the longer term, continued conversion of rural land to urban and developed uses will act to reduce the timberland base, in some cases removing the most productive lands. The 1992 to 1997 rate of expansion of urban and developed areas was higher than in previous periods, as the U.S. South's population has increased faster than the national average over the last decade. Projections show the South's share of total population increasing, as the Nation's population expands. FASOM results suggested, however, that substantial potential for expanding sustained forest production levels would still exist. Private investment could significantly modify the future timber supply outlook, with substantial increases in the share of timber harvest coming from plantations in both forest industry and nonindustrial private ownership.

At the same time, these results do not necessarily portend a future forest comprised solely of planted stands and uni-directional transitions to plantations. Projected increases in plantation area would concentrate timber production on fewer hectares, with more timberland passively managed and with less harvest pressure on naturally regenerated forests. But even with higher rates of plantation establishment, naturally regenerated forests would cover three-quarters of the future private timberland base and hardwoods would continue to be the dominant forest cover type. Recent forest survey remeasurement data for the southeastern U.S. indicate that less than half of final-harvested pine plantations on the large farmer and miscellaneous private ownership class are regenerated back to pine plantations, with 54% transitioning to other types: oak-pine (17%), naturally regenerated pine (16%), and hardwood types (21%) (Butler and Alig 2000). Transitions between planted and naturally regenerated stands also involve significant amounts of two-way flows even on the more intensively managed forest industry timberland base in the South, where approximately 30% of pine plantations revert to naturally regenerated forest types after a final harvest. The dynamics are also affected by planting rates, especially on NIPF lands, that can fluctuate notably over time in response to incentives such as government subsidy programs, and this has led in the past to important impacts on the regional age class distribution for pine plantations.

Using the FASOM model, we found a wide range of possible outcomes when comparing amounts of private tree planting under different scenarios involving assumptions about interest rates and capital markets. In contrast to the TNAA base case, FASOM projections suggest that changes in prices and profitability stimulate changes in private investment that act to counter the effects of policies such as reduced public timber harvest (Adams et al. 1996b). Because flexibility in response derives from forest investment and timber management intensification (Adams et al. 1998, Alig et al. 1999), however, any restrictions on private forest investment have significant impacts. Thus, the scenario limiting NIPF forest investment to recent historical levels led to lower 2030 plantation levels than in the TNAA base case, with higher log prices and reduced aggregate timber harvest. The overall impacts from limited NIPF forest investment were notably larger than those from variation in the discount rate. FASOM projections suggest that added investment could lead to substantially larger timber harvest volumes and lower prices than those in the TNAA base case (that reflect a continuation of recent behavioral tendencies by nonindustrial private owners).

Competitiveness of biomass feed stocks for energy (e.g., McCarl et al. 2000) and short-rotation woody crops for fiber (e.g., Alig et al. 2000) should be monitored in future work. Other tree planting has also been proposed in some international deliberations about how to address greenhouse gas emissions, and likewise may affect future markets of the types considered in this study. Private timberlands in the United States have the apparent biological and economic potential to provide larger quantities of timber on a sustainable basis than they do today, and future research could aid in reducing uncertainty through more attention to possible land use shifts, production technology, and associated factors affecting supply and demand of different products from the land base.

Acknowledgements

Many people have contributed to the development of the TNAA and FASOM modeling systems. The development of the TNAA family of models was supported in part by funding from the USDA Forest Service's periodic RPA Assessments. Development of the FASOM model was funded by the U.S. Environmental Protection Agency, Office of Policy Analysis, Climate Change Division, and the USDA Forest Service, Pacific Northwest Research Station. We wish to acknowledge the related contributions of Bruce McCarl, Texas A&M University, Mac Callaway, UNEP, Denmark, and Steven Winnett, EPA.

References

Adams, D. & Haynes, R. 1996. The 1993 Timber Assessment Market Model: structure, projections, and policy simulations. USDA Forest Service, Pacific Northwest Res. Stn., Gen. Tech. Rep., GTR-PNW-504, Portland, OR.

Adams, D.M., Alig, R.J., Callaway, J.M., McCarl, B.A. & Winnett, S.M. 1996a. The Forest and Agriculture Sector Optimization Model (FASOM): model structure and policy applications. USDA, Forest Service, PNW Research Station, General Technical Report PNW-RP-495, Portland, OR.

— , Alig, R., McCarl, B., Callaway, J. & Winnett, S. 1996b An analysis of the impacts of public timber harvest policies on private forest management in the United States. Forest Science 42(3): 343–358.

— , Alig, R., McCarl, B., Callaway, J. & Winnett, S. 1998. The effects of factor supply assumptions on intertemporal timber supply behavior: The cases of investable funds and land. Canadian Journal of Forest Research 28: 239–247.

Alig, R. & Wear, D. 1992. Changes in private timberlands: statistics and projections for 1952 to 2040. Journal of Forestry 90(5): 31–37.

— , Adams, D. & McCarl, B. 1998. Impacts of incorporating land exchanges between forestry and agriculture in sector models. Journal of Agricultural and Applied Economics 30(2): 389–401.

— , Adams, D., Chmelik, J. & Bettinger, P. 1999. Private forest investment and long run sustainable harvest volumes. New Forests 17: 307–327.

— , Adams, D., McCarl, B. & Ince, P. 2000. Economic potential of short-rotation woody crops on agricultural land for pulp fiber production in the United States. Forest Products Journal 50(5): 67–74..

Brooks, D. 1993. U.S. forests in a global context: An issue paper for the Resource Planning Act Assessment. USDA Forest Service Gen. Tech. Rep. RM-GTR-228. Rocky Forest and Range Experiment Station, Ft. Collins, CO. 24 p.

Butler, B. & Alig, R. 2000. Dynamics of forest cover changes in the South: Historical overview and projections. USDA Forest Service Gen. Tech. Rep. in process. Pacific Northwest Research Station, Portland, Oregon.

Chang, C., McCarl, B., Mjeldge, J. & Richardson, J. 1992. Sectoral implications of farm program modifications. American J. of Agr. Economics 74: 38–49.

Haynes, R., Adams, D. & Mills, J. 1995. The 1993 RPA Timber Assessment Update. USDA Forest Service Gen. Tech. Rep. RM-GTR-259. Ft. Collins, CO., Rocky Mountain Forest and Range Experiment Station. 66 p.

Ince, P.J. 1998. Long-range outlook for U.S. paper and paperboard demand, technology, and fiber supply-demand equilibria. In: Proceedings of the Society of American Foresters National Convention; Traverse City, Michigan; Sept. 19–23, 1998; Society of American Foresters: Bethesda, Maryland. 407 p. (330–343).

Johansson, P. & Lofgren, K. 1985. The economics of forestry and natural resources. Basil Blackwell, Oxford, U.K.

Johnson, K. & Scheurman, H. 1977. Techniques for prescribing optimal timber harvests and investment under different objectives. Forest Science Monograph 18.

Kuuluvainen, J. & Salo, J. 1991. Timber supply and life cycle harvest of nonindustrial private forest owners: An empirical analysis of the Finnish case. Forest Science 33(4): 932–945.

Mangold, R., Moulton, R. & Snellgrove. 1995. Tree planting in the United States. USDA Forest Service, State and Private Forestry, Cooperative Forestry. Washington, DC. 17 p.

Mauldin, T., Plantinga, A. & Alig, R. 1999. Land use in Maine: Determinants of land use in Maine with projections to 2050. Northern Journal of Applied Forestry 16(2): 82–88.

McCarl, B., Adams, D., Alig, R. & Chmelik, J. 2000. Competitiveness of biomass-fueled electrical power plants. Annals of Operations Research 94: 37–55.

Mills, J. & Kincaid, J. 1992. The aggregate timberland assessment system BATLAS: A comprehensive timber resource projection model. General Technical Report PNW-281. Pacific Northwest Research Station, USDA Forest Service, Portland, Oregon.

Moulton, R.J. 1999. Tree planting in the United States. 1997. Tree Planter's Notes. 49(1): 5–15.

Powell, D., Faulkner, J., Darr. D. et al. 1993. Forest resources of the United States, 1992. USDA Forest Service RM Gen. Tech. Rep. RM-GTR-234 (revised). Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. 132 p.

U.S. Department of Agriculture, Forest Service. 1973. The outlook for timber in the United States. USDA Forest Service Resource Report 20. Washington, DC: U.S. Department of Agriculture, Forest Service. 367 pp.

U.S. Department of Agriculture, Forest Service. 1988. The South's fourth forest: alternatives for the future. USDA Forest Service Resource Report 24. Washington, DC: U.S. Department of Agriculture, Forest Service. 512 p.

U.S. Department of Agriculture, Forest Service. 1990. An analysis of the timber situation in the United States: 1989–2040. USDA Forest Service Gen. Tech. Rep. RM-199. Ft. Collins, CO: U.S. Dept. of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 286 p.

Zhang, D., Buongiorno, J. & Ince, P.J. 1993. PELPS III: A microcomputer price endogenous linear programming system for economic modeling Version 1.0. USDA Forest Service. Research Paper FPL-RP-526. US Forest Products Laboratory: Madison, WI. 43 p.

— , Buongiorno, J. & Ince, P.J. 1996. A recursive linear programming analysis of the future of the pulp and paper industry in the United States: Changes in supplies and demands, and the effects of recycling. Annals of Operations Research: 68(1996): 109–139.

Total of 27 references