SUMMARY

The North American Pulp and Paper Model (NAPAP Model) is a recent modeling development. The model is designed to project the evolution of markets and technology of the pulp and paper sector in the United States and Canada. The model incorporates advancements in economic modeling of trade and environmental impacts within the pulp and paper sector. It is a regional market model, with five supply and production regions (Canada Fast and West; U.S. North, South, and West), U.S. and Canada demand regions, and additional trading regions representing Pacific, Atlantic, and Latin American markets. Regional markets and trade are modeled for all categories of paper, paperboard, and market pulp, and all categories of pulpwood and recycled paper. The model combines information on supply and demand, manufacturing technology, and transportation costs to compute regional market equilibria year to year, using a price-endogenous linear programming system. The model allocates annual growth in production capacity to processes and regions as a function of profitability and market conditions. This paper introduces the model structure, with a general description of methods, function of the model, and projections of accelerated paper recycling.

Keywords: Pulp and paper, model, economics, recycling

INTRODUCTION

The North American Pulp and Paper Model (NAPAP Model) was developed recently by the U.S. and Canadian Federal forestry agencies (USDA Forest Service and Forestry Canada). The NAPAP
Model was designed to assess long-range market trends and technological changes in the pulp and paper sector, such as increased paper recycling. Technological changes are projected as a behavioral response to changing market conditions.

The USDA Forest Service will use the NAPAP Model in conjunction with the TAMM Model (Adams and Haynes 1980) to provide an analysis of future paper recycling trends and impacts on timber supply and demand for the 1993 RPA Assessment Update. The Economics and Policy Directorate of Forestry Canada also conducts long-range studies of the forest sector, and the NAPAP Model will be used for such studies in Canada.

**METHOD DEVELOPMENT**

In the early 1980s, the University of Wisconsin-Madison Forestry Department developed a general computerized economic modeling technique, with support from the USDA Forest Service, Forest Products Laboratory (FPL) (Gilless and Buongiorno 1985). This regional market modeling technique, based on price-endogenous linear programming, was applied initially in the PAPYRUS Model of the North American pulp and paper industry (Gilless and Buongiorno 1987). The PAPYRUS model was primarily a regional market model, in which production processes were represented by activity analysis with immediate economic substitution among available technologies. Later, in support of the 1989 RPA Assessment, another economic model of the North American pulp and paper sector was developed at FPL, using the same methodology but with a more detailed specification of product grades and production technology. The model was known as the FPL Pulpwood Model (Ince and others, unpublished). The FPL Pulpwood Model added the technique of modeling technological substitution of production processes within each product grade as a competitive evolutionary process (Ince and others 1987). The FPL Pulpwood Model was designed to simulate gradual substitution of technology by allocating growth in capacity over time among competing production processes as a function of relative profitability, as influenced by changing market conditions.

Projections made with the FPL Pulpwood Model and Forest Service TAMM model in 1990 showed that paper recycling would accelerate in the 1990s with significant impacts on future timber prices and timber consumption patterns in North America. For example, instead of rising real timber prices in the South in the decades ahead, as projected previously, the analysis showed that timber prices in the South would be relatively stable (Ince 1990). Because of the significance of these findings and because additional research was needed to improve the technical structure and accuracy of the pulp and paper model, the USDA Forest Service and Forestry Canada launched a cooperative research effort in 1990 to develop an improved model of the North American pulp and paper sector. The result of the research effort since 1990 is the new North American Pulp and Paper Model (NAPAP Model). The new NAPAP Model provides a completely reestimated data set and a more thorough representation of the industry structure in North America. It includes all principal pulp, paper, and paperboard grades produced in the United States and Canada.

In addition to improvements in data and model structure, NAPAP Model development was accompanied by improvements to the price-endogenous linear programming technique. The general technique, developed at the University of Wisconsin-Madison, is known as the Price-Endogenous Linear Programming System, or PELPS (Gilless and Buongiorno 1985).

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The PELPS was applied in its original form in the PAPYRUS model (Gilless and Buongiorno 1987). Subsequently, a revised version of PELPS was developed for the FPL Pulpwood Model (Calmels and others 1990). The latest version of the system, PELPS III (Zhang and Buongiorno, in process), was developed recently for the NAPAP Model, following technical recommendations by FPL and the Economics and Policy Directorate of Forestry Canada. It operates efficiently on a desktop microcomputer. It allows specification of technical constraints related to paper recycling and waste management policy. For example, in the NAPAP Model using PELPS III, precise constraints are specified on recovery of paper for recycling, by placing upper and lower bounds on wastepaper supply for each grade of wastepaper. Upper bounds are specified as maximum percentages of paper and paperboard by grade that can be recovered for recycling. Thus, the upper bounds on wastepaper supply simulate “maximum feasible recovery rates” for wastepaper. Adjustment of this type of constraint can be used to simulate effects of changes in municipal wastepaper collection and recycling programs in the years ahead. Constraints can also be specified on minimum recycled fiber content in each paper and paperboard grade, similar to constraints that have been legislated in many states in the United States. Thus, the NAPAP Model, using the improved PELPS III modeling system, is capable of exploring many different scenarios related to the issue of paper recycling in North America.

Other improvements were introduced with PELPS III, such as the option to use Tobin’s Q-Ratio theory in determining the allocation of capacity growth among competing processes over time and the option to specify precise tariff and exchange rate assumptions (Zhang and Buongiorno, in process). In addition, a new input/output system programmed by Susan Phelps of the Economics and Policy Directorate, Forestry Canada, has greatly improved efficiency in handling data and display of NAPAP Model output.

THEORY

The NAPAP Model is an application of spatial equilibrium modeling theory, as conceptualized in general by Samuelson (1952). The modeling framework is the Price Endogenous Linear Programming System (PELPS) developed originally by Gilless and Buongiorno (1985) (also Gilless and Buongiorno 1987, Calmels and others 1990, Zhang and Buongiorno, in process). As such, PELPS provides a linear programming solution to the spatial equilibrium problem (Duloy and Norton 1975), in which there are supply and demand functions for commodities among different regions with interregional transportation costs. The problem is to find the optimal competitive equilibrium of prices, quantities supplied and demanded, and interregional trade flows. The optimizing behavior of the free market is simulated as the maximization of consumer and producer surplus each year among all markets and regions in the model. In addition, PELPS is an application of “recursive programming” (Day 1973) in which year-to-year solutions are found for the market equilibria, by dividing the long-term spatial equilibrium problem into a sequence of problems, one for each year. In this system, all markets are assumed to be perfectly competitive in each year, with no foresight regarding future market conditions. Thus, the NAPAP Model assumes implicitly that the long-run market behavior of the North American pulp and paper sector conforms to competitive free market behavior with temporal decision making. The NAPAP Model extends the theory by assuming that the allocation of growth in production capacity each year among production technologies is a behavioral process identical to the allocation of growth among production regions. The PELPS III manual explains the theoretical approach to allocation of capacity growth among regions and production technologies (Zhang and Buongiorno, in process).
On the demand side, the NAPAP Model includes demand functions representing five demand regions (United States, Canada Atlantic markets, Pacific markets, and Latin American markets). North American demand functions are included for each of 14 categories of final products (paper, paperboard, and dissolving pulp), which are produced in the United States and Canada. Demand functions include elasticity with respect to price and change in demand determinants, such as projected population and Gross National Product (GNP). On the supply side, U.S. and Canadian supply functions are included for five North American production regions, including U.S. North, South, and West and Canada East and West. Supply functions are included for hardwood and softwood pulpwood (roundwood and residues) and for four principal grades of recovered wastepaper. Supply functions include elasticity with respect to price and variables, such as projected regional timber inventories or sawmill residue output for pulpwood or projected landfill tipping fees for wastepaper (the alternative cost of wastepaper disposal).

Trade with regions outside of the U.S. and Canada is represented in the NAPAP Model by including net export demand functions and net import supply functions for principal trading regions. Export demand functions (exports outside of the United States and Canada) are included for products that are exported in significant quantities from the United States or Canada. Import supply functions (imports from outside of the United States and Canada) are included for products that are imported in significant quantities to the United States or Canada. Trade functions include estimated elasticities with respect to price and appropriate shifter variables (such as foreign economic activity indicators).

In addition, the model includes a highly detailed representation of production capacity and supply for all principal grades of market pulp, paper, and paperboard in all five North American production regions. Regional production capacity for each product is divided among one or more competing processes (such as recycled-fiber and virgin-fiber processes or chemical pulping and mechanical pulping processes). The processes in the model include all principal production processes that are used at the present time, plus future processes that are expected to become available for production at assumed future dates in the model. The aggregate product supply function is defined each year by the production capacity among the various processes and the production costs of each process among the various regions, combined with overseas import supply functions. The interaction between exogenous demand functions and aggregate product supply functions determines the equilibrium solution for product markets each year. The model includes also an endogenous solution of the regional supply and demand equilibrium for pulpwood and wastepaper, with regional demand determined by raw material requirements of production processes and the simultaneous equilibrium solution for paper and paperboard production. Capacity growth is allocated each year among the most profitable processes and regions, with exogenous constraints on capacity growth specified as a distributed lag function of past production.

As fiber raw material markets, product markets, and production technology evolve from year to year and as new production processes are introduced in the model, the regions and processes that experience the most capacity growth will change. For example, as long as technology and excess supply of wastepaper offer higher profitability to processes that use recycled fiber, the model will favor growth in recycling capacity, but increased recycling will put higher demand on wastepaper, eventually diminishing excess supply of wastepaper and profitability of recycled fiber processes. Over time, the model will show how wastepaper and pulpwood markets are expected to respond to shifting supply, demand, and changing technology and how technology is expected to evolve in response to market conditions (i.e., supply, demand, and prices for fiber inputs, pulp, paper, and paperboard products).
FURTHER DEVELOPMENTS

Linkage between the NAPAP Model and the USDA Forest Service TAMM/ATLAS system is being developed and tested. (The TAMM model is an economic model of the softwood lumber and plywood sectors and timber stumpage markets (Adams and Haynes 1980); it operates in conjunction with the ATLAS model of timber inventory and growth.) The linkage between the models is established by convergent solutions of timber supply and demand equilibria, obtained by iterative solutions of the NAPAP and TAMM models. The models are run iteratively until a convergent solution is obtained, with revised timber projections from one model used as data input for the other model on each iteration. Pulpwood market projections from the NAPAP Model are used as data input to the TAMM model. These include projected regional quantities and prices of pulpwood (roundwood and residues, hardwood and softwood) in the United States and Canada, including exports. In turn, timber projections from the TAMM model are used as data input to the NAPAP Model. These include projected timber inventory; sawtimber prices, and residue output by region (used to shift pulpwood supply functions in the NAPAP Model).

Empirical data for econometric estimates and technical assumptions in the NAPAP Model were obtained from many sources. Principal sources of data included the American Paper Institute (API), the Canadian Pulp and Paper Association (CPPA), the U.S. Commerce Department, Statistics Canada, Forestry Canada, and USDA Forest Service. In developing the model, we obtained substantial advice and guidance from experts in industry and from trade associations and industry research organizations including API, CPPA, PAPRICAN (Pulp and Paper Research Institute of Canada), FPL, and TAPPI (Technical Association of the Pulp and Paper Industry). We will invite further review and comment from industry experts this year, to refine the accuracy of data and assumptions in the NAPAP Model.

RESULTS

A fully operational version of the NAPAP Model has been available since January 1992. Efforts since then have focused on calibration of the model to historical data in the recent historical period. (The model runs from the year 1986, called the base year.) Calibration work involved adjustment of PELPS parameters (such as theoretical weighting factors in the capacity allocation formula) and adjustment of other assumptions, to bring the projected equilibrium solutions of the model into precise agreement with actual historical production, capacity, and price trends from 1986 to 1991. General validation of the PELPS methodology over longer historical times was previously demonstrated, by comparison of predicted and actual trends of the pulp and paper sector (see Zhang and Buongiorno, in process’, for examples). Further validation research is underway at the University of Wisconsin-Madison. At the time that this paper was submitted (February 1992), some preliminary projections were charted, but calibration work and development of linkage to the TAMM Model were proceeding. Therefore, results are expected to be revised and are not submitted in this paper. At the CINTRAFOR meeting, graphs and charts of preliminary results will be presented and discussed.

LITERATURE CITED


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