A World Review of Strategic Silvicultural Planning Processes that have Potential for Application to British Columbia
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by

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EXECUTIVE SUMMARY

The project reviewed strategic silvicultural planning processes in New Zealand, Sweden, Chile, the U.S. South, and the U.S. Pacific Northwest to identify tools, techniques, and approaches that could have value for silviculture in British Columbia.

These regions have emphasized incorporating economic considerations related to wood quality into strategic silvicultural policy. An important consequence has been an increasing emphasis on growing quality sawlogs. This trend, most pronounced in New Zealand, Chile, and Sweden, is starting to emerge in the U.S. South and Pacific Northwest. In short, quality will be a "winner".

No region was found to pursue a "top down" silvicultural strategy, targeted at producing a single end product or specific group of end products. Rather, a three level, "bottom up" planning framework was identified in silvicultural strategy. This approach consists of the following components:

- stand-level or crop planning
- regional supply projections
- dynamic regional or global economic modelling

Usually, all three components are used to examine and select the mix of stand-level silvicultural regimes that make up a regional silvicultural strategy. While some organizations (usually plantation estates) are managing forests to supply roundwood for pulp and paper facilities, most silvicultural programs produce an assortment of products that varies with ownership, species grown, and available sites, with quality sawlogs often being the major product.

The following specific recommendations are made.

- More resources should be invested in extending the range of species and silvicultural practices that can be considered by SYLVER, British Columbia's stand-level silvicultural decision model.
- Consideration should be given to developing standard price and cost assumptions for use by British Columbian silvicultural planners.
- More effort should be spent on using timber supply models to investigate the regional effect of silviculture and other policy initiatives.
- Consideration should be given to using an appropriate global supply-and-demand model to gain a better understanding of the place of British Columbia silviculture in world forestry, and possibly to help develop standard price and cost assumptions for use by silvicultural planners. It would be most effective to utilize one of the existing global models, rather than undertake this type of modelling directly.

A project should be initiated to develop an interim silvicultural strategy for a single provincial forest region using a combination of stand- and regional-level strategic planning techniques.
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1 INTRODUCTION

Forests are the dominant natural feature of British Columbia. No other province is as dependent on its forests since they are the main engine of the provincial economy and account for one in every nine jobs (twice the national average). The forests also support and shape the life styles of British Columbians in many nonmaterial ways, including the maintenance of attractive environments for work and leisure.

As the major land owner, the provincial government has tried to manage the forests of British Columbia with a high level of stewardship. An important component of this stewardship has been the provincial silvicultural program. The intention of this program has been to ensure the prompt reforestation of the 180,000 ha (approximately) that are harvested annually. Recently, significant effort has also been directed towards augmenting future wood supplies through intensive silviculture.

Although private industry is primarily responsible for reforestation following harvest, the Ministry of Forests (MoF) is directly responsible for reforestation of harvested areas as part of the small business program, and has also implemented the majority of the recently completed intensive silviculture projects. The MoF is also responsible for setting reforestation and intensive silviculture standards.

Given the long time horizons and broad scope of the provincial silviculture program, a strategic planning framework is essential to ensure that appropriate goals and objectives are established, and that execution is efficient and effective.

Sophisticated strategic silvicultural planning systems are being used in other countries. Although these systems are generally part of more mature silvicultural programs or are driven by a predominance of fast-growing, short-rotation species, components or features of these systems may be adaptable to the British Columbia silviculture program. Assessments of "state-of-the-art" have been commissioned in two general areas:

1. The basic end-product strategy that has been incorporated into various regional silvicultural programs.

2. The nature and extent of the uses of macroeconomic modelling of supply-and-demand to guide the strategic silvicultural planning process in various regions.

Individuals knowledgeable in present state-of-the-art strategic silvicultural planning in Sweden, Chile, New Zealand, the U.S. South, the U.S. Pacific Northwest, and British Columbia were contacted. To give structure and direction to these discussions, a background paper was developed describing the present situation in British Columbia, and outlining the specific topics of interest (Appendix 1). Many background papers and reports supplied by the contact group were studied, as well as other reports and papers.
2 STRATEGIC SILVICULTURAL PLANNING IN SWEDEN

Sweden has about 23.7 million ha of forest, with a standing inventory of 2.6 billion m$^3$. This resource is made up of 39% pine, 45% spruce, 11% birch, and 5% other deciduous species. About half of this forest is under private ownership, mostly in southern Sweden. The remaining half is almost equally divided between public and corporate ownership.

Of 56 million m$^3$ removed annually about 47% is allocated to pulp, 45% to sawtimber, 6% to fuel, and 2% to other uses.

2.1 End Products and Silvicultural Regimes

Sweden’s rich forest resources were heavily cut in the second half of the 1800s due to the rapid growth of the sawmill and pulpmill industries. All cutting was selective, with minimum diameters set at between 20 and 25 cm. Smaller trees were assumed to respond to the opening up of stands, so no attention was given to assisting regeneration. Natural regeneration did not happen, and by the early 1900s huge areas of secondary forest were in a degraded state, particularly in northern Sweden. In the 1950s the Swedish Forest Service started a program to reforest cutover areas. It also introduced clearcutting and developed silvicultural norms for clearing, scarification, controlled burning, nurseries, planting, and drainage. Application of the Forestry Act of 1948 eventually put a stop to selective cutting.

Labour costs rose sharply in the 1960s. To compensate, the forestry sector focused its attention on mechanization, improved work efficiency, and means of increasing yields. However, reforestation standards were not being met and reduction of the annual allowable cut was contemplated. More aggressive measures to improve forest yields were required, including:

- introducing lodgepole pine in the 1970s (planting of which has greatly diminished owing to disease outbreaks);
- closer planting;
- intensifying early cleaning (precommercial thinning); and
- fertilizing middle-aged to mature forests.

The National Board of Forestry now prescribes the desirable minimum and maximum stocking and volumes for pine and spruce at different ages and for different site classes. State and private growers can select their own regimes, provided they meet the Board’s stocking standards.

All regimes aim at growing high-quality sawlogs (clear of branches and defects). Growing pure pulpwood is simply too costly. The volume of pulpwod from a sawlog regime depends on species and tree size composition, and site productivity; most of it comes from thinnings, which make up 22–30% of national output.

Seventy-five percent of all cutover land is replanted at densities of 1300–2500 trees/ha. Stands are cleaned before they reach 3 m, commercially thinned one to three times, and fertilized at least once during the rotation period. Final harvest is at 65–130 years. Minimum and maximum ages are set by local forestry boards to meet expected volumes of sawlogs (of minimum 20 cm diameter).

The most commonly used tool for silvicultural decision-making is a model developed in the 1960s by the Swedish Cellulose Company, the largest landowner and forest industry company. This model sought to define:

- quantities of wood produced by silvicultural activities;
• cost of wood produced by silvicultural activities;
• nature of the production; and
• amount of capital and how long it is tied up.

Swedish Cellulose developed this model to determine the optimal levels of silvicultural effort, including planting densities, cleaning, draining, pruning, thinning, and fertilizing. It estimated the point at which the marginal cost of a treatment (combined with the resulting difference in harvesting and delivery costs) ceased to yield a profitable flow of timber (considering volume, dimension, and quality). The solution is complex because:

• there are wide variations within the treatments themselves;
• strong interactions exist between the effects of each treatment; and
• treatment effects on timber volume, dimension, and quality are difficult to define.

Swedish Cellulose's model was programmed and translated into detailed information packages specifying the alternative levels of effort needed for each silvicultural case to be profitable. In the 20 years before 1970, the company's silvicultural program was guided by these models and increased wood production increment by 25%, or about 1% annually. These decision-making approaches helped the company optimize its silvicultural investments. The company estimated that the increased harvest resulting from intensified silviculture yielded 10% return on capital.

2.2 Forecasting Domestic Supply and Demand

2.2.1 Supply

Supply forecasts are based on data from national inventories and permanent sample plots. The Royal College of Forestry has carried out seven national forest inventories since 1923, and started establishing permanent sample plots during the 1983–1992 inventory. Large forest companies carry out their own inventories at 5- to 15-year intervals. These were originally simple stock-taking for logging contracts and sale, but developed during the 1950s and 1960s into management and operational inventories.

Yield information is collected mainly by the Royal Forestry Institute's extensive network of permanent sample plots. In the 1960s, government and industry started establishing their own permanent plots to check the Institute's findings. Before 1968, all yield projections were for 10–20 years; they now extend to one rotation period, or 100 years.

The National Forest Survey has been developing the HUGIN-SYSTEM stand model since 1973. This simulates growth under different scarification, controlled burning, planting, sowing, natural regeneration, cleaning, fertilization, thinning, and final cutting prescriptions for Scots pine, lodgepole pine, and Norway spruce. The development of individual trees is simulated for existing forests and unit areas are simulated for "new" (planted) forests. Volume is allocated to sawlogs, pulpwood, tops, and noncommercial class, and the dry matter content of all tree components is also calculated.

During the last 20 years, the "normal yield" principle, based on national inventory data, has been used to compare actual yields with the "better half" of all forests on each site quality. This comparison shows that Sweden has vast forest tracts yielding far below their site potential. This approach identifies the poorly stocked forests on good sites that have the highest priority for felling and rehabilitating.

Before 1973, yield forecasting was based on standard yield tables. This was an inflexible approach because the tables only applied to naturally regenerated forests. Although these tables allowed for different precommercial thinning densities, they assumed standard thinning regimes and so did not allow for regimes changing in the future.

A key factor in projecting national or regional supply is knowing how to measure the willingness of private owners to cut their timber. Regulations can stop owners from cutting their timber, but cannot force them to
cut. Several attempts have been made to force owners to cut (for example, taxing annual growth of their trees) but these have never been politically acceptable. The actions of 250,000 owners holding 50% of the forest land, mostly in southern Sweden, have a major effect on supply.

Most owners would cut their timber if prices were high enough. A 1981 study of 165,000 owners having at least 10 ha of forest found that area, growth rate, production cost, existence of a management plan, taxation rules, age of ownership, and price all affected their willingness to cut timber. It concluded that a 10% price increase would lead to a 17% increase in timber supply, mostly from owners presently not active in the market. Active owners with existing contracts, management plans, and long-term obligations would be less influenced by price increases.

Poor reforestation and management of young forests between 1960 and 1970 could have an effect on future supply. Because this will not be felt for another 30 years, there is little incentive to take remedial measures that will only make the eventual effect on industry and the environment more severe.

A draft law submitted in February 1993 outlines a new forest policy that will rank wood-producing capacity equal to environmental values, although it is unclear whether owners, companies, environmental groups, or society as a whole would bear the cost of conservation. The new legislation is intended to remove most of the detailed reforestation and management prescriptions stipulated in the present Forestry Act. It will be the owners' responsibility to manage their forests as they see fit, provided they meet the legally required goals.

- **Population.** Per capita consumption of forest products increases in linear relation to per capita GNP, but this does not take into account price fluctuations or structural changes in the industry.

- **Economic growth.** Sweden saw steady economic growth between 1945 and the mid-1970s, but practically all forecasts since then (even outside the forestry sector) have been wrong. Predictions have proved to be little more than qualified guesses.

- **Technical factors.** Production processes and efficiencies continually change. For example, the wood needed to make a tonne of paper declined from 5.0 to 3.6 m³ between the 1960s and 1980s. This trend will probably continue with the ongoing switch-over from chemical to mechanical pulp production. The use of clay and ash filling materials may further reduce wood demand.

- **Product substitution.** Increasing use of metal, minerals, and chemical products to replace wood in the building sector will reduce demand.

### 2.3 Forecasting Global Supply and Demand

Sweden exports 90% of its pulp, 75% of its paper, and 60% of its solid wood products. Global changes can have a major effect on its economy. Eighty percent of Sweden's exports are to western Europe, and it is generally agreed that this will continue to be Sweden's main market for the future.

Sweden maintains a market-intelligence network throughout the countries that most influence its economy. More specific information is obtained from:

- studying relevant statistical publications;
- participating in multi-Teamed investigations (such as the European Wood Demand/Supply Study); and
- soliciting special consultant studies.
Despite these efforts, predictions can be completely upset by events such as the breakup of the USSR. The trend towards regional trading blocks (European Economic Community [EEC], Association of Southeast Asian Nations [ASEAN], Japan, USA-Mexico-Canada) will restrict global trade, as underscored by ongoing difficulties in GATT (General Agreement on Tariffs and Trade) negotiations.

Many Swedish companies are facing slow market growth, cyclical fluctuations in demand, and the need for high investment to increase or replace their processing capacity. To assist forest managers with their strategic planning, the International Institute for Applied Systems Analysis at Laxenburg, Austria (IIASA) developed a dynamic model that analyzes the future effect of global cost competitiveness on the Swedish forest sector. The model generates 15- to 25-year scenarios using different economic and policy assumptions. It has a domestic forest sector component that models interaction with forest sectors of other countries to generate trading scenarios. Each forest sector model describes all activities from timber growth to consumption of paper, lumber, and panels. Exogenous variables include Gross Domestic Product (GDP), population, price of substitutes, exchange rates, prices of input factors, and technological change.

The model's main elements are:

- **Demand.** The model calculates long-term demand for each product considered from per capita demand (in turn, a function of per capita GDP) and population growth, and predicts forest product prices in relation to prices of substitutes.

- **Product market.** The model calculates the long-term prices needed to cover variable and fixed production costs of lumber, panels, and pulp. Variable costs are made a function of each producer's operational scale. The forest sector's effect on market price thus reflects its relative size. Rate of mark-up is defined as a function of market imbalance. A market with excess supply is assigned a lower mark-up than one with excess demand. Price is an interactive factor in the model. Increasing relative prices eventually lower product demand, which in turn lowers prices. Falling prices reduce profits and availability of funds for investing in new capacity. Reduced investment in turn decreases long-term supply, which increases prices.

- **Supply.** The supply element has four modules:

  1. the forest industry module, which defines production capacity and processing costs, domestic forest resource supply, and wood imports. It consists of three submodules covering profits, cash flow, and production capacity:
      a) the roundwood market, which defines timber harvesting, wood imports and exports, and delivered wood prices;
      b) forest management, which defines potential roundwood supply based on existing forest resources, harvesting capacity, and harvesting costs; and
      c) inventory of standing volume, which defines the wood raw material base for the forest industry. However, the module makes no distinction between species, site qualities, age classes, or silvicultural treatments. It increases standing volume by an increment percentage (both defined as a function of stand density) and decreases it by mortality and harvest drain.

  2. the forest industry module links the whole system. It generates and gives potential supply and processing costs to the product market module. This in turn generates product price, actual demand, and market imbalances and feeds them back to the industry module;

  3. the construction sector module defines investment costs and processing efficiency for new capacity, which it feeds into the forest industry and forest management modules; and

  4. the forest sector regulation module establishes the amount of wood made
available for harvest by estimating an allowable annual cut as a function of the balance between cut (drain) and growth.

Further wood supply modelling of Europe has recently been completed at IIASA. The result has been a model that forecasts future wood supply by country. Although this model does not consider economics, it does model forest inventory in some detail. A new matrix-growth model of the Swedish forest was developed that represents the forest estate as a matrix of areas arrayed by volume and age class. The dynamics of growth are represented by rules that govern the movement or transition of areas between fixed states in the forest estate matrix. This methodology has been used to model many of the other European countries where age class data were available.

### 2.4 Forecasting Domestic and Global Prices

Historical prices do not seem to be relevant to future predictions. Instead, prices are dictated by future supply-and-demand balance trends. Sweden has orderly price negotiating systems, but there is no established procedure for forecasting prices. This can only be done by understanding the positions of all partners in price negotiations.

As with global supply, good market surveillance is essential to predicting events and trends that might affect prices. Examples of such events or trends follow:

- When Canada largely withdrew from the European market and the USSR all but disappeared, Finland and Sweden were able to recapture a portion of the market share with lowered prices.
- Sweden's timber imports are too small to influence national prices, but Swedish industry will continue to import cheap wood from the Baltic states and Poland, specifically to check local prices. Some sawmills will continue to import timber because they cannot afford to buy local sawlogs.
- In the 1980s, European importers lowered prices by purchasing cheap wood from Brazil and Chile. When the large European forest industries took remedial measures small buyers were unable to purchase this wood on the scale needed.
- European timber producers and sellers have noticed that buyers are paying more attention to wood quality, which could affect forest management regimes and future forest product price structures.
- For several decades, Sweden's annual forest growth has exceeded annual demand-and-cut, which means that there is room for industries to expand. But an increase in the annual cut could not be taken up immediately. A temporary supply surplus and price decline would result.
3 STRATEGIC SILVICULTURAL PLANNING IN CHILE

The focus of Chile's forest industry is on growing radiata pine for sawlogs and pulpwood (1.3 million ha) and, more recently, eucalyptus for pulpwood (200,000 ha). Seventy-five percent of the radiata pine planted in the last 30–40 years is owned or controlled by large forest companies. Fast growth, cheap land, low afforestation costs, and strict state environmental regulation over forest land make it attractive for forest companies and landowners to convert marginal agricultural land to forest plantations, particularly with eucalyptus.

Of the 11 million m³ of wood removed in 1987, 41% went to pulp, 38% to solid wood, and 21% to export.

The Chilean forest industry, almost wholly based on planted radiata pine, is fiercely competitive over land, the power to purchase plantation wood, plantation technology, and export market share. Each company must decide whether to grow their own wood or purchase from other sources, whether to grow pine or eucalyptus, and whether to export logs, chips, or pulp. Developing and using tools to assist strategic planning has been important to forest companies.

3.1 End Products and Silvicultural Regimes

Chile's silvicultural regimes are geared towards growing clear wood, sawlogs, and fibre.

1. Intensive regime for pine clear wood (with some sawlogs and fibre)
   - planting: 1000–1250 trees/ha
   - thinning to waste: to 600–800 trees/ha at 5–6 years
   - pruning: 2.0–2.5 m at 5–6 years; 2.5–5.0 m at 7–8 years; 5–7 m at 8–9 years
   - commercial thinning: to 250–350 trees/ha at 10–13 years
   - clearfelling: 25–28 years

2. Moderately intensive pine sawlog regime (with some fibre)
   - planting: 1250–1600 trees/ha
   - first commercial thinning: to 350–450 trees/ha at 10–13 years
   - clearfelling: 20–25 years

3. Low-intensity pine fibre regime (with some sawlog)
   - planting: 1250–1600 trees/ha
   - clearfelling: 15–23 years

4. Low intensity eucalyptus fibre regime
   - planting: 1600–2000 trees/ha
   - clearfelling: 8–12 years

3.2 Forecasting Domestic Supply and Demand

3.2.1 Radiata pine supply

With their strong orientation towards exports, Chilean forest companies are concerned more with domestic supply than with domestic demand. Radiata pine dominates supply. The potential of eucalyptus in Chile has only very recently been realized. Stand projection and supply models have not yet been calibrated for eucalyptus; supply is predicted by simple estimation of future yields and planted areas.

To forecast radiata pine supply, the main forest companies have willingly cooperated with the Instituto Forestal to develop plantation growth models. Medium-sized companies
rely more on intuition and published information to estimate local demand and prices, and few make any attempt to project domestic supply, global supply, or global demand. However, they do use growth models to evaluate the effect of different silvicultural regimes. The availability of these models has enabled companies to explore new options. While many companies practice only one silvicultural regime, others experiment with up to twelve.

A cooperative of the ten largest forest companies, formed in 1988, developed such a model. This model extended from a 1-year theoretical first phase, through a 2-year second phase using existing information, to a third phase (1992) based on data from permanent sample plots. Previously, in 1986, these companies had also cooperated in developing a radiata pine supply simulation model. This was followed in 1990 by the development of a linear programming model to help with strategic planning. Simulation models proved unsatisfactory because of difficulties in selecting adequate silvicultural prescriptions, and in satisfying physical, monetary, and regulatory constraints. These problems were solved by using linear programming optimization models. One such model, currently used by three companies, helps management to decide silvicultural management policies, long-range production levels, and land acquisition strategies. More specifically, its objectives are to:

- determine sustainable long-range optimal rates of production;
- determine the technical and economic feasibility of supplying timber to existing plants, and defining investment for new ones;
- estimate the potential value (and maximum price to offer) of new timber lands to acquire; and
- select optimum silvicultural regimes and prescriptions.

The model helps management to maximize its net present value subject to constraints of resource availability, long-range stability of the company, supply commitments, and silvicultural and technological factors. The model considers a 45-year horizon, divided into fifteen 3-year periods. It separates out the first 3-year period into a more detailed tactical model.

The model comprises the following components:

- Macro-stands. These are stands within a region that are alike in age, site quality, and initial stocking. The model considers up to 10 age ranges, 3 site-quality classes, 3 density conditions and 4 pruning schedules.
- Silvicultural prescriptions. The model defines prescriptions and timing for planting, commercial and noncommercial thinning, pruning and final harvest, and chooses an optimal subset of prescriptions from several alternatives.
- Timber production. The model determines sustainable production levels of pulpwood, sawlogs, export logs, and clear wood under the chosen set of prescriptions.

The model provides:

- optimal production in the planning period;
- destination of this production, areas to be treated by different silvicultural regimes, land to be acquired in the future, age and spatial distribution of plantations; and
- net monetary income in each 3-year period and net present value of the company.

The model has helped management to analyze the technical and economic feasibility of supplying existing plants, making investments in new facilities, and acquiring new lands, either already planted or suitable for planting. It has concluded (generally) that intensive silviculture for producing quality timber should be concentrated on the best sites, leaving pulpwood to be grown on poorer ones. It also reveals that most companies prefer to grow and use sawmill-quality wood, rather than use short-rotation fibre-only regimes, with pulpmill requirements being met from thinnings, other low-quality logs, and residual sawmill chips.
The Instituto Forestal periodically publishes a projection of radiata pine wood availability (currently for the period 1990–2019). It uses an iterative simulation model to project plantation yields given current data on age class distribution, and to yield tables and management regimes for companies and small owners in three macro-regions. It assumes:

- future forestation rates;
- proportion of plantations under intensive, moderately intensive, and low-intensity silvicultural regimes;
- yields under each regime; and
- losses to fire, insects, and disease.

The projection separates sawlogs and pulpwood from final fellings and thinnings for the three following scenarios:

- fixed rotation for the intensive, moderately intensive, and low-intensity regimes, indicating the opportunity to produce more wood (when available) in favourable markets;
- nondeclining maximum wood supply, reflecting long-term potential; and
- nondeclining medium-term wood supply adjusted to expected actual production, which reflects the most realistic situation.

### 3.2.2 Domestic demand

Companies are less interested in domestic demand than in supply because so much of their production is exported.

Those companies growing clear wood simply estimate "reasonable" levels of future demand. One major company growing clear wood is pioneering a more sophisticated demand model that takes into account consumption of clear wood in windows and doors, mouldings, and furniture.

Pulpwood companies estimate the needs of all papermills using fibre raw material to decide their own wood procurement strategies. The largest paper-making company, Compañía Manufacturera de Papeles y Cartón S.A. (CMPC), forecasts national paper supply and demand by:

- assessing the capacity of competing plants and their current projects; and
- projecting product demand based on population and GDP growth, and on its evaluation of potential market penetration by new products.

### 3.3 Forecasting Global Supply and Demand

The global sawlog and pulp market situation is of great interest to Chilean companies, but few have undertaken global demand projections themselves. Most have simply tailored information for their own needs from outside sources, such as:

- specific supply-and-demand studies by consultants (Recent studies have included a 20-year outlook of world markets for Chilean radiata pine timber and solid wood products, and a world supply and demand balance for eucalyptus fibre.);
- published market information; and
- special reports made by national and multilateral agencies, and by consulting companies.

Projections are made for packaging-grade sawlog demand in Japan, Korea, China, and Turkey, and for lumber demand in the Middle East, Europe, and Japan (among other countries and regions) to estimate "reasonable" rates of increase.

Greater attention is being paid to timber quality, yet it is difficult to estimate demand and price levels. Because companies must rationalize the extra cost of intensive silviculture to grow quality timber, there is a
great deal of interest in developing the appropriate supply-and-demand models. The approaches are still in their infancy. Since there is very little published information, companies must still rely on simple estimating. The following elements are considered important:

- production of radiata pine clear wood by Chilean companies and small owners;
- production of radiata pine pruned logs in New Zealand and the assumed clear wood recovered from them;
- production of ponderosa and other pine clear wood from the U.S. based on U.S. Forest Service information on lumber outturn by grade; and
- production of European clear wood based on historical trends.

3.4 Forecasting Domestic and Global Prices

Historic trends and future supply-and-demand conditions are used for predicting local sawlogs prices, but no attempt has been made to project prices for lumber in Chile.

The following approaches for estimating price trends for Chile's main product groups have been used:

- **Export sawlogs and packaging-grade lumber.** Since these are mature markets, projections are made using historic price trends. Two years ago, a consultant developed an econometric model to predict U.S. pine prices and to assess the relative position and market influence of Chilean radiata pine.

- **Pulplogs.** Prices are determined by projecting production costs of logs, chips, and sawlogs from different geographic sources, and by considering the effects of pulpwood exports.

- **Clear wood.** No definite approaches have been decided. The first relevant publication appeared in 1992, but it did not mention how radiata pine might affect the U.S. market. Potential prices for clear radiata pine in Europe are estimated from prices for similar products. Potential Japanese prices are based on current sales.
4 STRATEGIC SILVICULTURAL PLANNING IN NEW ZEALAND

Like that of Chile, New Zealand's forest industry is almost completely dependent on radiata pine. Of 1.2 million ha under plantation, 1.1 million ha are planted with radiata pine. About 75% of New Zealand's pine plantations are currently held by forest product processing companies.

Of the 10.6 million m³ outturn in 1988, 39% went to the pulp industry, 41% to solid wood, and 20% to fuel.

4.1 End Products and Silvicultural Regimes

New Zealand's silvicultural regimes aim at growing clear wood and sawlogs. Fibre is produced from thinnings and tops, and no standard regimes have ever been dedicated to producing fibre alone; but this is a contentious issue. With increased privatization of plantations, some companies are starting to test shorter rotations for fibre production.

The clear wood and sawlog regimes are generalized as follows:

1. Intensive regime for pine clear wood
   • planting: 850 trees/ha
   • thinning to waste: to 350 trees/ha at 5 years; to 250 trees/ha at 8–9 years
   • pruning: 5, 7, and 9 years
   • clearfelling: 25–27 years

2. Moderately intensive pine sawlog regime ("framing" regime)
   • planting: 1000 trees/ha
   • thinning to waste: to 450 trees/ha at 7–8 years
   • commercial thinning: to 250 trees/ha at 17–20 years
   • clearfelling: 25–27 years

4.2 Forecasting Domestic Supply and Demand

With such a large plantation area dedicated to a species that responds so well to crop manipulation, New Zealand has achieved pre-eminence in plantation management.

The New Zealand Forest Service started increasingly complex intensive silvicultural trials in the early 1960s. By the late 1970s the Forest Service had accumulated so much information that it was almost impossible to interpret it, or to communicate research results to forest managers and planners. Economic models of that time attempted to bring these data together. They included tree-quality factors, extended evaluation beyond the forest into processing, and stressed economic rather than biological or social criteria. However, their conclusions were not readily accepted by conservative forest managers. Rather than simplifying the options, these models seemed only to diversify the choices. Almost any regime could be justified by subjectively weighting the assumptions.

By 1978 there was a proliferation of regimes, few of them anywhere near optimum. The Radiata Pine Task Force was created to determine and rationalize silvicultural regimes. It developed a radiata pine growth simulation model called SILMOD to use the results of 20 years of research into this species. The model predicts size, quality, and net present value of radiata pine stands for almost any site, silvicultural treatment, or rotation, as well as for a range of processing options.

This model helps to determine the best timing of tending schedules, and explores the financial implications of new tending options.

Some general conclusions from this model have been:
- intensive forestry does not necessarily increase costs per cubic metre, and can greatly improve future returns if operations are timely and efficient;

- intensive forestry can reduce harvest volume;

- aspects of wood quality that were previously considered important (such as density and branch size) are not as economically significant as other factors, such as log size;

- log size, site productivity, and distance from the processing plant were the most important factors in determining profitability;

- other important factors include selection of final crop stocking, rotation, timing of pruning and thinning, mill conversion factors, the choice of minimum sawlog size, and certain overhead costs;

- maximum volume production, which requires high stocking, is incompatible with maximum profitability; and

- optimum rotation age varies considerably according to the combination of regime, site, price, and processing factors.

A conversion planning model extends and updates SILMOD for a range of products. It consists of the following set of modules and databases, which can be used individually or in combination:

- a stand assessment inventory system that combines a cruising procedure and a dynamic log bucking model, and estimates volume by log grade, small-end diameter, and taper;

- a stand prediction model that predicts log outturn by log grade. Subcomponents of this include a growth model, a stand volume generator that estimates diameter distributions and log assortments, log quality predictions, and a log grade predictor;

- detailed models for sawmills and plywood plants that accept resource data input, and have components for short-term plant design and management analysis (for example, the sawmill model includes a sawing simulator, a machine demand calculator, a sawpattern selection model, and a dynamic mill-flow model);

- log yield models that predict the physical yield and residual log value associated with processing logs of different characteristics in different processes (including sawmilling, plywood, export logs, export chips, MDF, hardboard, particleboard, bleached kraft pulp, newsprint, linerboard, and ethanol); and

- linear programs for allocating logs toidders to maximize sellers' revenue and for allocating a log resource among competing plants depending on market demands and plant capacities, and economic models for comparing regimes, simulating the status and flow of resources from a forest estate, and selecting an optimal management strategy.

Regional supply forecasts used to be made by applying yield tables to plantation age class distributions for the expected rotations. These were always broken down by species, and sometimes by silvicultural regimes as well. Harvesting ages were adjusted to avoid major fluctuations in harvest levels. As yield tables became more reliable, harvest projections included a breakdown by size and quality. Forest and regional administrative unit projections were accumulated into national ones.

Since the privatization of state forests, forestry has become less of a strategic issue, and the state has largely withdrawn from making supply projections. Most companies use advanced harvest scheduling models that optimize returns under given management constraints; but they require detailed knowledge of the resource, and application of appropriate yield models.
5 STRATEGIC SILVICULTURAL PLANNING IN THE U.S. SOUTH

The southern United States is heavily forested with both softwoods and hardwoods. A long tradition of private property rights has left owners relatively free from restrictions on land use. Silvicultural regimes vary widely across the region according to landowners’ objectives. Increasingly, these are for nontimber values, such as wildlife and recreation.

Removals of softwoods currently exceed growth. The reverse is true for hardwoods, but demand has increased markedly in recent years. Timber supply-and-demand forecasting is very important for softwoods, and several models have been developed to project timber inventories.

5.1 End Products and Silvicultural Regimes

5.1.1 Softwood

Softwoods comprise the main commercial species of the U.S. South, and about half of the current inventory. About 10% of all softwood forests are publicly owned. These are managed by the U.S. Forest Service, state governments, and the U.S. military. These agencies acquired much of this land in the 1930s and 40s. At that time these forests were populated with already maturing loblolly and longleaf pine. These forests have traditionally been managed for high-quality timber on rotations of 40–75 years, with two or more thinnings.

Environmental factors are now a priority. The Federal Endangered Species Act requires that federal lands be managed for the benefit of endangered species, which means a decline in output of high-quality timber. For instance, much public pine forest is now retained as open mature and maturing stands for the red cockaded woodpecker.

The forest industry owns, or controls through long-term leases, about 25% of forest lands; since the 1960s it has managed these lands largely for pulpwod and small sawlogs. Rotations vary between 20 and 30 years. Twenty-three to 25 years is most common, but rotations can be as short as 18–20 years for pulpwod. Only a few companies in Louisiana and eastern Texas grow sawlogs and veneer logs.

Technology and market forces have changed pine silviculture since the early 1990s. The use of effective low-cost herbicides is replacing mechanical site preparation, and permits weeds to be controlled for two or three years longer. This alone raises yields from 7 to 14 m$^3$ per hectare per year. Some companies are also fertilizing their stands once or twice, which is estimated to increase yields to 20 m$^3$ per hectare per year.

Reduced output in the West makes it attractive to produce lumber and panels in the South, so companies thin their stands as early as 12 years, and extend rotations to 25 years to produce a mix of sawlogs and pulpwod.

About two-thirds of the South’s forest land is held by nonindustrial landowners, but this ownership is shifting from farmers to corporations, including financial institutions and pension funds. At least 25% of the South’s forests are near cities, and land values are influenced more by real estate factors than by silviculture. Stands are small and getting smaller. In Georgia, for example, over 40% of nonindustrial stands are smaller than 10 ha. Many institutions, therefore, own land for speculation. In many areas they are overcutting pine forests, and current growth is only 65–70% of removals.

The government’s Conservation Reserve Program, intended to retire farm lands in the late 1980s, resulted in large-scale planting of pine across the South, which will increase growth in this decade.
5.1.2 Hardwood

Public hardwood lands, mainly in mountain areas, have been managed for sawlogs on 60- to 100-year rotations. They have high recreational value, and the public is calling for reduced harvest levels.

A few companies own and manage hardwood bottomlands, to produce pulpwod and sawlogs using natural regeneration, with clearcutting on 30- to 35-year rotations. Recent expansion of hardwood pulping plants, and a market for exporting chips to Asia, have made this an important resource.

Despite a large hardwood inventory, future supplies are uncertain due to the terrain, high harvesting costs, and the unwillingness of owners to sell. Past high-grading has further reduced the quality and sawlog potential of many stands.

5.2 Forecasting Domestic Supply and Demand

Considerable work has been done to develop models to forecast supply and examine the effect of alternative silvicultural regimes at the stand level. Most of these models have been developed for pine plantations, but some models can project natural pine and mixed pine-hardwood stands. Some work has also been done on hardwoods and cottonwood, pure yellow poplar, and upland oak-hickory stands. The most commonly used models for pine are:

- Georgia Pine Plantation Simulation (GAPPS), developed at the University of Georgia;
- PTAEDA (Loblolly Pine growth model), developed at Virginia Polytechnic Institute;
- YIELD plus, developed by the Tennessee Valley Authority; and
- COMPUTE–P LOB (Loblolly Pine growth model), developed by the U.S. Forest Service.

Many of the larger landowning forest products companies have developed proprietary models for internal use. The Weyerhaeuser SEER model is thought to be the most advanced, although Union Camp, Westvaco, and International Paper have done significant work on growth and yield. GAPPS and COMPUTE–P LOB are plantation-based models and have limited application for natural stands. PTAEDA and YIELD plus can be used with some natural stands. PTAEDA is a distance-dependent, individual tree growth model, while the other models are stand-level models. All models will produce stand and stock tables, and assortments of volume for different end-product specifications based on small end top diameter and diameter at breast height (dbh). Modelling log quality and end-product outturn has not been done in the U.S. South, although it has been suggested that Weyerhaeuser and others may have incorporated end-product recovery forecasting provisions into their stand-level models.

Early efforts at projecting regional timber supply-and-demand relied on simple analyses of forest inventory data, published periodically by the Forest Inventory and Analysis work units of the U.S. Forest Service. Strategic planning has, until recently, been done by the private sector. In the 1970s and 1980s, industry made wide use of linear programming models to schedule harvesting on their fee and leased timber lands. By combining land and stumpage prices and interest and growth rates, these models identified 20- to 25-year rotations for pulpwod and small sawlogs as the optimal regimes.

The early demand projections were based on increases in population, disposable personal income, housing, and paper products usage and assumed that future demand for timber would increase linearly according to existing trends. These models, often called "gap" models because they predicted that future timber demand would exceed supply, assumed existing levels of inventory, removals, and constant real prices for forest products. They used the Timber Resource Analysis System (TRAS), an inventory projection model that tracked the number of stems per average hectare by species and diameter class, and "grew" them using appropriate diameter class growth and mortality rates derived from remeasured regional growth plots.
In the 1990s the U.S. Forest Service moved from TRAS and "gap" modelling to more sophisticated econometric modelling. This was coupled with the Timber Resource Inventory Model (TRIM), a new inventory projection model developed in the Pacific Northwest.

TRIM (renamed ATLAS in 1990) is an area-yield model that projects timber inventory based on species, stand type, land area, and yields. It simulates timber growth, inventories, management, area changes, and removals over the designated projection period. Changes in areas of forest ownership and forest types, used as input for TRIM, are generated by the Southern Area Model (SAM).

TRIM projects the biological forest inventory conditions and works iteratively with the Timber Assessment Market Model (TAMM), a national economic model that estimates future supply-and-demand for stumpage and timber products in various national and regional subdivisions. Together, the two models project regional timber supplies by incorporating economic and forest inventory data.

Southern timber supply was projected for the period 1990–2030 using TAMM, TRIM, and SAM. The results were then disaggregated into state-level data using the State Allocation of Regional Inventory Model (SARIM). Although TAMM, TRIM, SAM, and SARIM represent sophisticated mathematical approaches for modelling state timber supplies, critics questioned the accuracy of disaggregating national and regional projections into state and lower levels. It was felt that the state-level information itself was unreliable.

Researchers developed a simpler model to better project future timber inventories at the state level. Regional stand management classes and age class structures were used to develop the Georgia Regional Timber Supply Model (GRITS). It is similar to a stand projection growth model, except that it advances volumes through age rather than diameter classes. The advantages of GRITS are:

- it is simple to understand and use on a microcomputer (the database is contained on a Lotus spreadsheet) so that it is easy to change inputs to determine how they affect supply;
- it is able to project timber supply on a regional basis for any reasonably sized unit that has accurate forest inventory data;
- it is reasonably accurate despite being less complex than national supply models; and
- it is flexible in analyzing a wide variety of possible timber situations, including the effects of adding or closing product processing capacity.

GRITS is now used with forest inventory and analysis data to project management type by owners, species, and age using growth and removal rates for each forest area identified by the owner. Although GRITS was developed for the State of Georgia, it has been adapted recently for other southeastern states (Virginia, North Carolina, South Carolina, and Florida). The results of this work have not yet been published. A number of forest products companies are also using GRITS to forecast wood supply for individual mill procurement areas.

A consortium of university, industry, and U.S. Forest Service researchers is currently being formed to address forest resource modelling in the South, and, specifically, the following issues:

- subregional shifts in demand due to changing stumpage prices;
- merging growth and yield techniques with GRITS;
- chip availability;
- sawtimber versus pulpwood availability;
- effects of intensive silviculture;
- urbanization of the South;
- landowner attitudes and motivation; and
- potential effects of regulations.
6 STRATEGIC SILVICULTURAL PLANNING IN THE U.S.
PACIFIC NORTHWEST

6.1 End Products and Silvicultural Regimes

While management of most of the forestland in British Columbia is under the direction of the Ministry of Forests, land ownership in the Pacific Northwest is very diverse. Consequently, land management objectives and the resulting silvicultural programs are also diverse. In very broad terms, in the Pacific Northwest about 50% of the forestland is under government ownership, while the remaining private forestland is about equally divided between large industrial ownerships and small private holders. Most of the government land is owned by the Federal government, but both the State of Washington and the State of Oregon own significant areas of high site land. Most of the Federal land is National Forest land managed by the U.S. Forest Service, but the Bureau of Land Management (BLM) manages a significant area of high site land in western Oregon.

Silvicultural strategy is changing on government ownerships because of concern for environmental and other issues, but traditional silvicultural programs have been organized to promote prompt regeneration following harvesting. Most harvesting has been done by clearcutting, and harvested areas are usually planted; but selective harvesting is common in the interior part of the Pacific Northwest and more use is being made of other silvicultural systems, such as the shelterwood system. The U.S. Forest Service and the BLM usually plant 1500 trees/ha. Plantation spacing on state lands depends on the degree of slope. On gentle slopes that are considered to have potential for commercial thinning, about 1000 trees/ha are planted; on steeper slopes, about 900 trees/ha. Intensive silviculture in regenerating stands has been limited on the national forests, but some pruning is being done. Considerable investments have been and are being made in intensive silvicultural programs on BLM lands and state lands. These practices include precommercial thinning and fertilization.

Silvicultural strategy on private land is going through a period of considerable change. With the exception of Weyerhaeuser, most private landowners do not seem to have a long-term strategy, but instead are motivated by legal requirements and the economics of meeting these requirements.

Both Washington and Oregon States have "Forest Practice Acts" that influence silvicultural strategy on private lands. In Washington, the Forest Practice Act was recently revised (1988) to lower the number of seedlings that must be established following harvest. The Act now requires that "A minimum of 190 vigorous, undamaged, well-distributed seedlings per acre of commercial tree species" (470/hectare) must be established following harvest. Further, the Act requires that "competing vegetation shall be controlled to the extent necessary to allow establishment, survival and growth by commercial species." The requirements of the Oregon Forest Practice Act are similar to this 1988 revision.

Before 1988, Washington State's Forest Practice Act required that a significantly higher number of seedlings be established (300/acre–740/ha). Private landowners have reduced the number of seedlings planted because of the extra planting costs and precommercial costs associated with narrow plantation spacing. Generally, high-quality bareroot seedlings produced from genetically improved seed are used. Site preparation such as burning is limited, and the reduced number of seedlings allows the tree planters to search out the better planting spots, and, if necessary, spot-prepare planting sites. Most landowners anticipate some natural regeneration, especially on coastal sites, and reduce plantation spacings accordingly.

Most of the growing stock on private land is now second- or third-growth, and many of the stands are less than 30 years old. Before 1990 plantation spacings were much higher. Weyerhaeuser led this trend with its "target
forest" approach. Consequently, many of these stands have had to be precommercially thinned to ensure a reasonable tree size at the desired rotation age, commonly between 50 and 60 years. Many of these stands were also fertilized following precommercial thinning. Hopefully, reduced plantation spacing will reduce the need for much of this commercial thinning. With recent increases in log prices, many private landowners have initiated significant commercial thinning programs, although some have held back for fear that thinned stands would attract spotted owls. Some private landowners now emphasize fertilization of older stands; some are also considering pruning, and Weyerhaeuser has initiated a pruning program.

6.2 Forecasting Domestic Supply and Demand

Considerable use has been made of stand-level growth models to examine alternative silvicultural regimes, and to investigate the possible effect of intensive silviculture on yield. These include DFSIM, SPS, and ORGANON. Recently, emphasis has been shifted to examining the effect of silviculture on the quality and value of output. Most new research has focused on Douglas-fir, but ponderosa pine has also been considered. Work has included mill recovery studies with a range of tree quality classes including pruned logs, development of knot models linked with growth models, and the development of decision-support PC software. These decision-support software tools have the following features:

- They utilize individual tree descriptions developed by growth models or measurements on actual trees. These descriptions include information on tree size and quality characteristics such as the size and distribution of knots and juvenile wood.

- They utilize product recovery information that relates product recovery to tree and log characteristics. Product recovery information is by grade and includes lumber, plywood, chips, and kraft pulp.

- They utilize product price information by grade and product manufacturing cost information.

- They utilize information on harvesting cost that is sensitive to tree size and volume harvested.

- They produce summary economic criteria for alternative silvicultural regimes and alternative log-bucking strategies.

Use of these tools has indicated that wide spacing is financially more attractive than close spacing, and that pruning is financially attractive for Douglas-fir. The mill recovery studies on which these models are based also indicate that the effect of silviculture on tree and log size alone does not directly relate to end-product value. While lumber volume recovery was found to be strongly linked to log dib and taper, visually graded lumber grade recovery was primarily linked to the size and distribution of knots. For MSR lumber, lumber grade recovery was primarily linked to the size and distribution of knots as well as to the amount of juvenile wood. Volume recovery of veneer was found to be linked to log dib as well as to the size and distribution of knots, while veneer grade recovery was primarily linked to the size and distribution of knots.

Both Washington and Oregon states have completed long-term supply projections using state-level forest estate models. These studies included extensive scenario analysis that examines a range of silvicultural alternatives. Key features of these strategic studies included the use of detailed forest inventory data, subregional projections, consideration of possible effects on wildlife habitat, and projections of the regional economic effect of alternative scenarios.

Local supply-and-demand forecasts are also components of the Timber Assessment Market Model (TAMM), a large national forest sector model developed by the U.S. Forest Service. TAMM was developed to supply long-term projections of consumption, production, prices of forest products, and the development of the

1 diameter inside bark
2 machine stress rated
forest resource. Tamm is a solid wood products and wood supply model, with pulp, paper, trade, and land use shifts being modelled externally. While Tamm is a U.S. forestry sector model, it does include the Canadian forestry sector, since the two are interrelated. The Canadian Forestry Service is also using Tamm in Ottawa.

Tamm is integrated with ATLAS, an inventory projection model that uses yield tables and age class information to project the forest inventory over time, given harvests and silvicultural investments. Timber supply is related to stumpage prices and available inventory. Timber supply projections are developed separately for hardwoods and softwoods, for public and private lands, and for four geographic regions: North, South, Rocky Mountains, and Pacific Coast.

Tamm demand forecasts are based on estimates of aggregate economic activity and of consumption of solid wood products in key end-use areas such as residential housing. Consumption and price forecasts are produced for key generic solid wood products such as hardwood and softwood lumber, structural and nonstructural panels, and for paper and board. Two Tamm generic softwood solid wood products groups that are important for British Columbia are the Douglas-fir subregion (Pacific Coast) lumber group and the ponderosa pine subregion (Rocky Mountains) lumber group. Tamm forecasts a single, all-species, all-grade lumber price and volume for each group. For the Pacific Coast this price is equal to the all-grade price for Douglas-fir, while for the Rocky Mountains it is equal to the price of a specific mix of ponderosa pine boards. The actual prices for other species groups produced in each subregion will cluster around this generic price. For example, coastal hemlock-fir prices were about 80% of the all-grade coastal Douglas-fir prices in the 1980s.

Scenario analysis with Tamm examined issues such as levels of harvest on public lands, rates of improvement in technology, recycling rates, and acid rain. Recent scenario analyses found that future timber scarcity may not be as important an issue as earlier studies indicated. Consequently, long-term price increases may be moderate.

6.3 Forecasting Global Supply and Demand

Global supply-and-demand modelling is being done at the Center for International Trade in Forest Products at the University of Washington, using the Global Trade Model (GTM) (Section 8).

The U.S. Forest Service has also done limited supply-and-demand modelling of the Pacific Rim from its Seattle office, and has published the first supply-and-demand projection that distinguishes among log grades. This work examined the supply-and-demand for four log grades and made explicit consumption and price forecasts for two: a construction grade, similar to a "J" grade in British Columbia, and a performance grade, similar to an "H" or "I" grade log in British Columbia. These forecasts were done for relatively short periods considering the requirements for strategic silvicultural planning (i.e., 15 years); nevertheless, they indicate that real prices for higher-grade logs may increase at significantly faster rates than for lower-quality logs.

6.4 Forecasting Domestic and Global Prices

The Tamm model also produces price forecasts for lumber and other forest products, but the resolution is limited to a generic all-species, all-grade prices by region. Price forecasts for a full range of end products for each major species are necessary for strategic silvicultural planning. These price forecasts should be based on an understanding of the future supply-and-demand of individual grades by species. Presently available supply-and-demand models are not this sophisticated, and improving them could be a major undertaking.

As a first step, the U.S. Forest Service has developed price forecasts by grade for 10-year periods until the year 2040. These forecasts are for Douglas-fir, coast and interior hemlock-fir, and ponderosa pine, and are based on the Tamm price forecast for the generic lumber price for the Pacific Coast and Rocky Mountains. These price forecasts were developed by examining historical price
relationships among the generic Tamm all-species, all-grade price, the price for other species and grades, and a trend projection of the future grade mix. Although this approach is useful, it may not adequately describe the dynamics of future prices for high-quality items that are becoming increasingly scarce.

These grade-specific price projections help evaluate silvicultural alternatives that will affect log quality and end-product quality. They suggest that higher grades will experience the largest price increase, and emphasize the importance of considering wood quality when undertaking stand-level silvicultural planning. From a procedural viewpoint, these projections are quite useful to Pacific Northwest silvicultural planners since they cover all the major species (and product grades within species) in a consistent manner. The grade definitions were also selected to emphasize the differences in value between the various grades of structural and appearance lumber items, as well as the differences between normal and wide structural lumber.

7 STRATEGIC SILVICULTURAL PLANNING IN BRITISH COLUMBIA

7.1 Background

Of British Columbia's total area of 94.8 million ha, 80.7 million ha (85%) are designated as "provincial forests." About 45.7 million ha are productive, of which 24 million ha are currently available, harvestable, and growing commercial forests on a sustained-yield basis. One percent of this available productive forest is harvested each year. Allowable annual cut is about 75 million m³.

The Ministry of Lands (MoF) is mandated to manage and protect provincial forests for the maximum benefit of all British Columbians. This is a complex task. While encouraging a vigorous, efficient, and world-competitive timber processing industry, the MoF must accommodate grazing, fisheries, wildlife, water, recreation, and other natural resource values.

British Columbia's annual planting program is the largest in Canada with 230 million seedlings planted on Crown land in 1992. This is three times the number planted 10 years ago. About 50% of all harvested areas are planted; the remaining areas are regenerated naturally. Forest companies are legally responsible for reforesting all sites they harvest.

Before cutting any trees, companies must prepare "preharvest silviculture prescriptions" that describe how and when sites will be reforested. Only after public scrutiny and consultation does the MoF approve these prescriptions and issue cutting permits. Penalties for failing to meet reforestation prescriptions are severe and include reducing allowable annual cut and charging double for any reforestation work needed to meet required standards.

A federal-provincial Forest Resource Development Agreement (FRDA I, 1985–1990) provided $300 million to reforest the backlog of lands not satisfactorily restocked. The program, which involved site preparation, planting, brushing, weeding, fertilizing, thinning, and research, reduced this backlog by 35% during the agreement period.

7.2 "Basic" Silviculture

More immediate strategic and field decisions must be made about the most appropriate species and stocking levels for British Columbia's future second-growth forest.
These decisions influence future stand structure, biodiversity, economics, utilization, forest health, and rotation lengths. Prescriptions are set to satisfy "basic" silviculture (which is the legal definition of standards required to be carried out by forest companies). Basic silviculture includes all the activities needed to reforest recently denuded areas with commercially useful trees, and to monitor performance in meeting those standards.

In selecting species and stocking standards, the key elements are:

- knowing and using the inherent silvical characteristics of species suited to a site;
- knowing and mapping the soils and climatic features of forest lands; and
- carefully matching these basic elements with the land management objectives by prescribing appropriate treatments.

The Silvicultural Interpretations Working Group of the MoF has drawn up specific guidelines for selecting species and stocking levels. Additional "basic" standards are being developed by the Maximum Density Committee of the MoF to set the upper stocking levels permitted for lodgepole pine. Standards have also been developed for dry-belt Douglas-fir.

Species are selected by evaluating maximum sustainable productivity, crop reliability, silvicultural feasibility, and management objectives based on current knowledge of each site series, the silvics of each species, and the growth and development of second-growth forest. The guidelines are tied into British Columbia's forest ecosystem classification system, developed by the Ministry of Forest's Research Branch over the last five years. The intent is to standardize treatments on the same ecosystem, regardless of forest administrative boundaries. The guidelines have been developed with sawlog production in mind, but they are flexible enough to meet site-specific nontimber objectives also.

Species are first categorized as primary, secondary, or tertiary, and as preferred or acceptable, according to their evaluated rating. The guidelines specify minimum and target stocking levels of free-growing and well-spaced trees (planting and natural regeneration combined) for each primary, secondary, and tertiary species on each bioclimatic zone and subzone. A free-growing tree is defined as one occupying a 1-m radius cylinder that is 25–50% above the height of competing vegetation.

The guidelines have set these stocking standards to consider:

- trade-offs between piece size, value, and maximum volume production;
- safe pathological rotation age, considering projected pest risks;
- recognition of higher planting costs associated with higher stocking, and increased harvesting and milling costs with smaller piece sizes;
- avoidance of repeated stand entries;
- ability of coastal Douglas-fir to attain fuller site occupancy at lower densities than other species; and
- the need for management units with different objectives to have different stocking standards, subject to approval.

### 7.3 "Incremental" Silviculture

Since the forest land base and allowable annual cuts are forecast to decline in some areas, there is great interest in increasing forest yields through "incremental" silviculture. This legal term refers to optional activities such as surveying, thinning, fertilizing, and pruning that improve the value and growth of immature forests. Detailed studies are being undertaken for developing prescriptions, including pruning of lodgepole pine, and juvenile spacing of coastal and interior wetbelt Douglas-fir, coastal and interior hemlock, and interior lodgepole pine and spruce.

### 7.4 TASS/TIPSY

The primary stand-level growth model used to examine silvicultural alternatives in British Columbia is the Tree Stand Simulator (TASS) model developed by Ken Mitchell. This model simulates the development of individual trees
and stands given initial spacing and subsequent stocking control. The MoF has made TASS available to silvicultural planners in the form of a table look-up program called TIPSY. TIPSY is a PC-based program that contains a series of TASS-generated output tables covering a range of initial stocking and stocking-control alternatives for a number of British Columbia species growing in pure, even-aged stands. The basic relationships that drive TASS have not been developed for all species covered by TIPSY. For some species, such as western redcedar, redcedar site index models were used in conjunction with TASS relationships for other species to generate the TIPSY look-up tables. At present, TIPSY excludes some important species such as sub-alpine fir, and some management alternatives such as pruning, commercial thinning, and fertilization. TIPSY is also limited to pure even-aged stands. Work is presently underway to include commercial thinning in TASS/TIPSY.

Although the TASS model simulates branch development, TIPSY output is limited to volume, and does not cover tree or log quality.

7.5 Douglas-fir Task Force and SYLVER

British Columbia is shifting from a reliance on old-growth forests to more intensive management of second growth. Developing the basic data and tools for planning future strategies is vital. The first priority is to understand the relationship between site quality, stocking density, thinning, pruning, and fertilization regimes, and product types, quality, and value for the main commercial softwood species. Obtaining such data is difficult and time-consuming considering British Columbia’s long rotation periods. Forintek Canada Corporation established the Douglas-fir Task Force to:

- estimate the physical, mechanical, and chemical properties of the future intensively managed coastal Douglas-fir resource;
- determine the value of this resource for conversion to dimension lumber and pulp; and
- develop a computer model capable of evaluating the effects of silvicultural treatments on end-product values.

The task force studied a sampling of 60 trees from second-growth Douglas-fir for relative density, juvenile wood transition, chemical properties, longitudinal shrinkage, fibre length, density and chemical properties, unbleached kraft pulp, and refiner mechanical pulp. A further 299 trees were converted to 752 logs to study log and lumber yields, kiln drying, strength and stiffness, and heartwood treatability of the lumber products.

Data from this research were used to develop all the basic parameter relationships and input for (SYLVER), a stand-level model that simulates the effect of silvicultural treatments on forest yield, lumber value, and economic return and ranks the merits of each.

The current version of SYLVER only applies to second-growth stands of coastal Douglas-fir, but work on interior lodgepole pine should be complete within a year, and on hemlock within three years (with anticipated funding).

The principal elements of SYLVER are:

- TASS, which grows trees and stands on a prescribed site and under prescribed silvicultural treatments;
- Bucking (BUCK) and Sawmilling Simulator (SAWSIM) programs, which produce logs and lumber from the trees grown by TASS;
- A Grading Routine (GRADE), which classifies the lumber according to quality; and
- A Financial Analysis System (FAN$Y), which determines the discounted net revenue recovered from tending, harvesting, and processing the stand.
The output from FAN$Y must be interpreted and integrated with other management information before decisions can be made on selecting sites and stands, treatments, and the timing of treatments.

SYLVER's ability to include timber quality is a powerful feature. Without considering wood quality, SYLVER suggests that coastal Douglas-fir planting densities of 400–500 trees/ha would give better return on investment than the current practice of 900 trees/ha, and that stands on highly productive sites should be harvested at 50–60 years. Taking end-product quality into account expands the optimum planting density range to 500–750 trees/ha and delays harvest age to 90. The model also suggests that pruning would increase net present value; a single lift to 6.5 m at age 20 would result in clear lumber representing 14% of the volume and 73% of the lumber value.

7.6 British Columbia Silviculture Planning Model

The MoF has commissioned the development of a regional yield projection model similar to those found in the other countries examined in this report. This model, FOREST, was developed by the Forest Economics and Policy Analysis (PEPA) Research Unit at the University of British Columbia. FOREST was developed using MoF inventory and yield information and other economic information. This model was specifically designed to examine the regional effect of alternative silvicultural strategies. Strategies can be examined with economic as well as employment criteria, although the range of stand-level management alternatives that can be examined is limited.

7.7 Forecasting Domestic and Global Prices

Resource Information Systems, Inc (RISI) is a commercial economic forecasting organization that produces price forecasts on a subscription basis. RISI maintains two large econometric models of the forest products industry—a solid wood products model and a pulp and paper model. The solid wood products model (FORSIM) has significance for British Columbia as three B.C. lumber items are included in the price forecasts produced by the model: SPF 2 by 4 standard and better, SPF studs and hemlock 2 by 4 standard and better. A number of U.S. Pacific Northwest lumber items are also included. Once a year, annual prices are forecast for the next 15 years. On occasion, longer-term price forecasts have been made.

The Strategic Services Division of H.A. Simons has also recently completed a study of long-term British Columbia log, lumber, and chip prices for Forestry Canada. This study examined historical production and price trends for coast and interior logs and lumber by species and grade/quality grouping and historical coast and interior chip production and prices. This study also developed econometric models for estimating future prices by 10-year periods to the year 2040. For coastal species, a log price model was developed for three log quality groups for Douglas-fir, hemlock, balsam, and redcedar. For interior species, a single all-species, all-grade log price model was developed. A coastal all-grade lumber price model was developed for Douglas-fir, redcedar, and hemlock while a single all-species, all-grade interior lumber price model was developed. A separate chip price model was also developed for coastal and for interior chips. The approach used to model future coastal log prices by quality groupings was similar to the approach used by the U.S. Forest Service to model lumber prices by grade in the Pacific Northwest (Section 6.4) in that the model considers changes in the supply or scarcity of individual log quality groupings as well as the historical relationship between the prices of individual quality groups for each species.

Although the H.A. Simons study did not consider as detailed a mix of end products as did the U.S. Forest Service study, both studies concluded that future prices will increase faster for higher-quality products.
8 GLOBAL FOREST SECTOR MODELLING

As all strategic silvicultural planning must be adaptive concerning long-term global supply and demand trends, a consideration of global forest sector modelling must be included as part of this assessment. At present, there are two major global forest sector modelling efforts underway—the Global Trade Model (GTM) and the Timber Supply Model (TSM). Additional global forest sector modelling is also being done by organizations such as the World Bank.

8.1 Global Trade Model

The GTM was originally developed as part of the Forest Sector Project at IIASA. This model was developed by a team of international scientists between 1981 and 1985, and a final report describing the development, structure, and results of various scenario analyses was completed in 1987 (Kallio et al.). The GTM represents the first global forest sector model, and is based on 18 geographic regions and 16 forest products groupings. Each region is represented by a timber supply model, a forest industries model, and a products demand model. All regions are linked by a world trade model based on transportation costs and other factors. North America is represented by four regions: Western Canada, Eastern Canada, Western U.S., and Eastern U.S. Product groupings include five wood supply components: coniferous logs, nonconiferous logs, coniferous pulpwod and chips, nonconiferous pulpwod and chips, and fuelwood. The regional wood supply models also differentiate four wood supply components: large and small coniferous trees, and large and small nonconiferous trees.

The developers of the GTM have stressed that the model was designed for policy analysis, not as a forecasting tool. Specifically, the model was developed to examine the development of forest products consumption and price as well as forest products trade and timber supply, given various forest policy assumptions. In the words of the developers:

The emphasis was on issues of major relevance to the industrial and governmental policy makers in different regions of the world who are responsible for forest policy, forest industrial strategy and related trade policies. These include investment strategy related to production facilities, forestry plantation programs, and forestry infrastructure, such as roads needed to access timber in remote locations.

The developers also stressed that policy analysts must execute their own policy scenario analyses with the GTM to derive the maximum value from the model.

A key lesson from developing the GTM was that a global outlook is important when considering timber supply issues. Again in the words of the developers:

When regions are linked by trade, the effect of changes in one (or a few) regions is dampened by adjustments in other regions and by changes in trade flow. Therefore, national forest sector models that ignore import and export demand will tend to overstate the sensitivity of economic responses to policy interventions.

Following the completion of the GTM, responsibility for maintenance and evolution was transferred to the Center for International Trade in Forest Products (CINTRAFORE) at the University of Washington in Seattle. CINTRAFORE has since augmented the GTM and used it for several timber supply policy studies in the northwest U.S. One of the major changes has been to increase the geographic resolution of the model. The resolution of the Canadian component has been increased by recognizing British Columbia as a separate region from interior and eastern Canada. The geographic resolution of the U.S. component has also been significantly enhanced by increasing the number of U.S. regions from two to ten, including a subdivision of the Pacific Northwest into six regions according to timber ownership: westside public, westside private, eastside public, eastside private, inland public, and inland private. The states of Alaska and
California are also included as individual components. The resolution of the Pacific Rim has also been increased with important new regions such as New Zealand and eastern Russia being added.

Recent work by CINTRAFORE with the augmented GTM also illustrates the importance of a global perspective when considering long-term timber supply issues. For example, a recent policy analysis of the effect of decreases in timber supply from Pacific Northwest National Forests (Perez-Garcia 1991) indicated that a long-term reduction in supply from 18 million m$^3$ to 10.1 million m$^3$ (a 44% drop in supply) on westside national forests would result in a long-term price change from $46.50/m^3$ to $49.30/m^3$ (a 6% increase) in the price of sawlogs. The disproportionate change in price is the result of global increases in supply from other sources and regions.

The Director of CINTRAFORE, Bruce Lippke, has indicated that the GTM is available through CINTRAFORE for further policy scenario analysis. Mr. Lippke has also noted that any major changes in the British Columbia supply could have at least as much effect on global prices as the 6% increase in price expected for westside national forests in the Pacific Northwest.

8.2 Timber Supply Model

The TSM (Sedjo and Lyon 1990) differs from the GTM by focusing on timber supply. In the TSM, the world timber supply is divided approximately equally between responsive and nonresponsive timber supply regions. The responsive regions are assumed to respond economically to increased demand for industrial roundwood by increased investments in silviculture and additional harvesting in areas with high wood costs, while the nonresponsive regions are assumed to have limited potential to change future timber production. The responsive region is disaggregated into 22 timber supply regions while the nonresponsive region is disaggregated into 3 timber supply regions. For each responsive region, the model contains estimates by age class of area, volume, and harvesting and transport costs. British Columbia is represented by two regions: a fully accessible, relatively low wood cost area represented by forests with ages from 1 to 80 years, and a high wood cost area represented by forests with limited access and with ages over 80 years. The U.S. Pacific Northwest is represented by four regions, as is the rest of Canada. The rest of the U.S. is represented by eight regions. The final two regions are an Asia-Pacific region representing tropical hardwoods, and an emerging region containing the large, expanding areas of fast-growing plantations in the southern hemisphere, the tropics, and the Iberian Peninsula of Europe.

The model uses a basic, unified world demand relationship to represent demand. The objective of the model is to examine the transition of the present world wood supply from a mix of old-growth forest, secondary and managed forests, and fast-growing plantations to a forest dominated by secondary and managed forests, and fast-growing plantations.

The results of scenario analysis with both models (Arnold 1991) have indicated that:

- long-term projections of world forest sector supply-and-demand trends and prices only indicate what might happen, not what will happen;
- the two models do not indicate a world wood shortage as many previous policy analysis studies assumed; and
- long-term world demand for industrial wood is abating, and the responsiveness of world wood supply will probably limit large long-term increases in the real price of industrial roundwood.
9 DISCUSSION

A first step in integrating the experience of these various geographic regions with strategic silvicultural planning is to identify a common planning framework. One useful model would recognize three levels of strategic silvicultural planning:

1. stand-level or crop planning;
2. regional supply projections; and
3. dynamic regional or global economic models

Stand-level or crop planning is a very traditional forest management/silvicultural planning procedure that has been extensively undertaken in all regions. This type of strategic silvicultural planning consists of examining an array of alternative silvicultural regimes and then selecting the regime or set of regimes that best meets predetermined management objectives. This approach is based on developing an input/output model or production function at the stand level. Traditionally, these models have stressed inputs and outputs in physical terms (wood volume and possibly its assortment), but now most models also consider financial inputs and outputs. There is general appreciation that stand-level strategic silvicultural planning must consider the effect of alternative tending regimes on final product output. Many of the more sophisticated stand-level modelling efforts such as the SYLVER model do this. An interesting development in stand-level modelling, advocated by the U.S. Forest Service, is the concept of a target stand. This approach focuses on consensus development of target stand structures that will best support a wide range of resources values, rather than on attempting to manage stands to produce specific target outputs, such as quality sawlogs.

The second level of strategic silvicultural planning, regional timber supply projections, has also been widely implemented. Basically, this approach performs a scenario analysis by applying a forest estate model to a large region, such as a state or province. These scenarios usually include a range of strategic silvicultural alternatives. The "Projections of Future Timber Resources" section of the 1984 B.C. Forest and Range Resource Analysis is an example of this approach. Normally, this level of strategic silvicultural planning uses a very low level of resolution with respect to outputs, and often economic considerations are not included. If economics are included, this is not done dynamically with respect to supply, demand, and price. Rather, economic considerations may be used to help determine which silvicultural regimes are most likely to be (or should be) used.

The third level of strategic planning is represented by dynamic forest sector models that consider supply, demand, and prices. The best examples of this approach at a national level would be the Swedish model (Section 2) and the U.S. TAMM model (Sections 5 and 6). The global GTM and TSM (Section 8) are also examples of this approach.

All three levels of strategic silvicultural planning have a place in any comprehensive strategic silvicultural planning program. Although it would be preferable to replace them with a single global model, this is not practical at this time. What is both appropriate and practical is the application of these three levels in a sequential and iterative "bottom up" approach. With this approach, detailed crop planning is the foundation for regional planning, and global planning is influenced by the results and requirements of crop and regional planning. Stand-level or crop planning is needed to develop the basic understanding of the interaction of stand growth relationships, silvicultural practices, pest effects, and product/value recovery, location, and terrain for the more important species mixtures that are biologically feasible. Region-wide yield analysis is needed to assess the effect of silvicultural and other programs on outputs from the province's forests. Dynamic global supply-and-demand modelling is needed to develop the basic assumptions required by the lower two levels of modelling, to assess the global
competitiveness of British Columbia’s silvicultural program, and for other policy scenario analyses.

**Strategic silvicultural planning system**

**Crop planning**
- growth and yield
- product recovery
- location
- terrain
- cost and revenue
- pest consideration

**Regional planning**
- regional resource data
- IRM requirements

**Global planning**
- supply/demand
- price trends

An alternative would be a “top down” approach based on developing a desired “end-product profile” that a silvicultural program should be structured to produce. The clear wood strategies of New Zealand and Chile might be an example of this approach, but even in these countries, with their relatively simple silviculture programs (single-species, even-aged plantations) and short planning horizons, no simple, single end-product strategy is followed. A problem with this approach is that it does not consider the cost of producing given end products on different sites. British Columbia is characterized by a complex array of forest sites. Each site is suitable for a number of species, and many different silviculture practices or regimes may be appropriate on the same site, depending on other nontimber management objectives. It may be cost-effective to grow and deliver an end product on some sites, but not on others. Conversely, it may be cost-effective to grow and deliver the same end product with one silvicultural regime, but not with another that may be required by nontimber objectives. For this reason, the three-level approach would appear to be more useful.

Based on the review of other regions, it is clear that SYLVER, the model presently available for stand-level strategic silvicultural planning in British Columbia, is world class. Little can be suggested in the way of improvements except, perhaps, the rate of development of models for additional species and silvicultural treatments.

With increased attention being given to nontraditional silvicultural approaches such as "new forestry," there is increasing interest in modelling stands with complex species composition and structure. This might seem to be a logical extension of the development of TASS and SYLVER, but it would probably be more useful to first expand the model to other species such as coastal balsam, subalpine fir, redcedar, and yellow-cedar, and to include a full range of traditional silvicultural treatments such as commercial thinning and pruning. Consideration could also be given to incorporating log and wood quality resolution into models that are already able to deal with mixed-species stands, stands with complex structures, and alternative silvicultural systems such as PROGNOSIS. Although other models may not track individual tree characteristics at the same level of detail as TASS or SYLVER, simpler characterization of wood quality attributes may be an interim solution until TASS and SYLVER are fully developed.

It will be some time before the tools are available to complete detailed crop planning for all the major species in the British Columbia, or for a single MoF forest region. Until SYLVER is available for all species, crop planning for other species and silvicultural practices will be limited to consideration of volume output. It may be possible to use past-mill recovery studies and average tree size as a substitute, but it would seem more prudent to focus resources on expanding the coverage of SYLVER.

The development of economic assumptions such as future prices and costs is one area of stand-level planning that could be improved.
Other regions use generic, long-term product price projections from dynamic supply-and-demand models to develop long-term price projections by species, grade, and (possibly) size. This may be applicable to British Columbia. An alternative approach would be to expand on price forecasting.

Long-term price forecasts are very uncertain. The degree of uncertainty is directly related to the length of planning horizon and is high in British Columbia, where long rotations are used. Considerable uncertainty is also associated with yield and product recovery assumptions. A good example is the different suggested "best" initial plantation spacings recommended for Douglas-fir by the U.S. Forest Service stand-level model, and by SYLVER. The U.S. Forest Service work indicated that a lower initial spacing was best. Although both studies considered final product outturn, the use of a different mix of assumptions and empirical models resulted in different conclusions about the most appropriate silvicultural strategy. Two important conclusions were:

1. it is important to consider implementing a portfolio of silvicultural regimes to diversify risk; and

2. extensive sensitivity analysis should be a major component of all stand-level crop planning activities.

Based on what is being done in other regions, more regional or provincewide supply projection and policy scenario analyses should be done. Although the normal TSA and TFL yield analysis procedure will answer many of the relevant questions about the strategic effect of silviculture, these analyses are usually not current for areas as large as forest regions, and have more resolution than may be needed to answer policy questions. Ideally, a regional model should be capable of examining the change in the timber profile (size, quality, and species mix) over time, the effect of silviculture on these changes, and the interrelationship between silviculture and wood-growing and delivery costs. A major effort is now being made to incorporate actual ground locations and environmental considerations into TSA and TFL yield analyses. These considerations may be difficult to incorporate into regional and provincial supply forecasts, and this potential problem would need to be addressed.

The dynamic supply-and-demand modelling being done in other regions reveals two issues: the importance of a global perspective; and the considerable effort required to undertake this level of strategic planning. An examination of past supply-and-demand analyses also indicates the nature of the global constraints under which the British Columbia silviculture program must function. The long-term responsiveness of world wood supply will probably limit real increases in the price of wood. The consequence will be to limit the level of silvicultural investment that can be justified in British Columbia. Silvicultural planners will need to consider the wood-growing costs resulting from alternative regimes applied on different sites, and limit silvicultural investments to regimes and sites that generate competitive wood-growing costs.
10 CONCLUSIONS AND RECOMMENDATIONS

This review indicates that the major emphasis of strategic silvicultural planning in other regions of the world is on incorporating the economic effect of wood quality. An important consequence of this has been an increasing emphasis on growing quality sawlogs. This trend is most pronounced in New Zealand, Chile, and Sweden, but is also starting to emerge in the U.S. South and Pacific Northwest. British Columbia has also started to do this, but significantly more effort is required.

The tools and approaches available for stand-level strategic planning in British Columbia (e.g., SYLVER) are world class, and effort should be invested in expanding the range of species and silvicultural practices that the model will consider. Economic assumptions used for stand-level crop planning such as price forecasts can be improved, and an effort should be made to formalize and strengthen the cost and price assumption information that is available for silvicultural planners.

Compared to other countries, scenario analyses to examine the global effect of silviculture and other policy activities are inadequate. This is one area that should be considered for further effort.

Finally, more use should be made of global supply-and-demand models to better understand the place of British Columbia in world silviculture. A modest approach would be to work with CINTRAFORE to undertake scenario analyses using the GTM to examine silvicultural policy issues from a British Columbia viewpoint. It might also be possible to work with CINTRAFORE to increase the resolution of the GTM with respect to geographic regions and product grouping of specific relevance to British Columbia.

To develop these recommendations further, a project should be initiated to develop an interim silvicultural strategy for a single provincial forest region using a combination of stand-level and region-level strategic planning techniques. This would be based on grouping the forest inventory for a region into appropriate site and species groups and developing a range of silvicultural regimes for each site/species group. The volumetric and economic consequences of each regime would be estimated using the best available tools and information such as TASS/TIPSY and SYLVER. This would involve modelling yield, product out-turn, harvesting, and other costs as well as future end-product prices. Extensive sensitivity analysis would also be completed to develop an understanding of the potential variability of outputs from each regime. Finally, the range of regimes would be included in a regional model such as FEPA's "YIELD" to investigate the consequences of implementing various silvicultural portfolios at the regional level. Some consideration would need to be given to including provisions for environmental and other constraints in the regional model. Considerable care would need to be taken to clearly separate this strategic silvicultural modelling effort from the ongoing location-specific yield analysis work being done on TSAs and TFLs to help establish local AACs. The objective of this strategic silvicultural modelling should be to examine the consequences of alternative silvicultural portfolios at a regional level and develop a recommended mix of silvicultural treatments. The actual selection and assignment of regimes on a location-specific and site-specific basis should be considered as a separate issue that would be addressed as part of the yield analysis and PHSP process.
REFERENCES


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APPENDIX 1. Background Paper: A World Review of Strategic Silvicultural Planning Processes that have Potential for Application to British Columbia

1.0 Introduction to British Columbia Silviculture

British Columbia, Canada’s most western province, maintains a large and growing silviculture program and is continually striving to increase the efficiency and effectiveness of this program.

Forests cover over 60% of the total 95 million hectares of British Columbia. These forests supply a wide range of benefits to the Province’s 3.1 million inhabitants. About 4.0% of this total forested area is managed as commercial forest and this area produces an annual harvest of about 75 million cubic metres. The forest industry, which depends on this harvest, is the main driver of the economy of British Columbia and accounts for 1 in 9 jobs.

About 180 thousand hectares of forest or about 1% of the commercial forest is harvested each year. Most of this harvest is now accomplished by clear cutting, although about 8% is accomplished by partial cutting and this area will probably increase. Commercial thinning is not yet extensively applied in British Columbia, but this will change in the future as more second growth forests develop.

Most of the commercial forest land is owned by the Province, but the forest products industry conducts most of the harvesting under various forms of long-term licences and leases. The forest industry is also responsible for reforestation following harvesting and reforestation requirements are very stringent and are vigorously enforced. Although natural regeneration is used to regenerate some sites, planting is more common and amounted to over 200 thousand hectares during the last fiscal year. This 200 thousand hectares included areas recently harvested as well as areas that had been denuded by past fires, harvesting and other natural disturbances.

Although the British Columbia forest industry is responsible for the execution of most of the present silviculture program, the Silviculture Branch of the Ministry of Forests is responsible for setting the standards which this program must meet. This has been done primarily through required "stocking standards" which all reforestation projects must meet. These "stocking standards" have been developed with sawlogs as the primary product objective and basically determine the site-specific silvicultural regimes that will be implemented throughout the Province. They specify a different target and a minimum number of well-spaced, free-growing seedlings that must be established for each ecosystem found in the Province. They also specify a maximum allowed time period in which these "stocking standards" must be met. Seedlings growing closer than 2 metres are not considered well-spaced and free growing is specified in terms of the relative sociological position of seedlings and competing vegetation. In the case of lodgepole pine (Pinus contorta), which is often regenerated naturally, a maximum number of seedlings is also specified and stands that exceed this number must be given a thinning to waste to achieve the "stocking standards." This additional maximum density requirement for lodgepole pine will result in a very significant increase in the areas thinned to waste in the near future.

The application of more intensive silvicultural practices such as precommercial thinning, fertilization and pruning has been more limited, but recent reallocation of commercial forest land to other uses and age class unbalance in some forest management units have resulted in increased interest in more intensive silvicultural practices. The potential for silvicultural programs to increase the local employment base has also become more widely appreciated by the government of British Columbia. In response to these forces,
the British Columbia Ministry of Forests has budgeted for a doubling of areas spaced and fertilized and a quadrupling of areas pruned over the next five years.

British Columbia is characterized by a temperate climate which results in relatively modest forest growth rates. As a consequence, rotations are commonly over 50 years long and often over 100 years long. The forests are also characterized by large areas of mature timber and over 50% of a typical forest management unit will be stocked with mature timber. Given these long rotations and large areas of mature timber, the Province has been slow to realize the importance of developing a strategic, market-driven silviculture policy that links silvicultural practices to anticipated end product markets.

2.0 Strategic Silvicultural Planning in British Columbia

The Ministry of Forests is now well aware of the importance of harmonizing the provincial silvicultural program with long-term end product market forces and a considerable amount of effort is being invested in strengthening strategic silvicultural planning processes.

The Ministry of Forests recently commissioned an overview study of probable future end product markets and the implications of changes in world end product markets to silviculture in British Columbia.

Considerable effort has also been invested in developing quantitative tools that can be used to strengthen the strategic silvicultural planning process in British Columbia. Foremost among this effort is the work that has been done to develop the TASS growth model. TASS is a distance-dependent growth model which models the development of individual trees including individual branches within the crowns of trees. TASS has been calibrated for most of the major species that are important to British Columbia silviculture and enables silvicultural planners to assess the impact of various silvicultural regimes on volume and tree quality. The utility of TASS has also been increased by linking it to a sawmill simulator. In addition, a number of mill recovery studies that examine the relationship between log characteristics that can be influenced by silvicultural practices and product recovery have been completed.

Although considerable work on forest sector macroeconomic modelling has been done in British Columbia, this work has generally not had a significant influence on the provincial silvicultural program.

The stocking standards discussed earlier also attempt to consider the link between silvicultural and end product markets, but the quantitative analysis used to develop the present "first approximation" of the stocking standards was very limited. Standards for thinning to waste have recently been developed by the Ministry of Forests and these standards are based on considerable quantitative analysis that did attempt to consider the financial relationship between silviculture and end product markets. Work is also underway to develop standards for commercial thinning and pruning which will also be based on detailed quantitative analysis.

3.0 The Project

The Ministry of Forests is well aware of the considerable sophistication of the strategic silvicultural planning systems and approaches that are being used in some countries and regions within counties. In most cases, the more sophisticated approaches are being driven by more mature silviculture programs and/or by a predominance of fast-growing, short rotation species. The Ministry of Forests is interested in assessing the potential to adapt these systems and approaches to the British Columbia silvicultural program. Specifically, the Ministry of Forests wishes to assess the "state-of-the-art" in two general areas:

- The basic end product strategy that has been incorporated into various regional silvicultural programs.
• The nature and extent of macroeconomic modelling of supply and demand used to guide the strategic silvicultural planning process in various regions.

4.0 Requested Assistance

The Ministry of Forests has commissioned Reid, Collins and Associates to undertake this assessment. Reid Collins maintains a head office in Vancouver, British Columbia and is the forest resources consulting division of HEA. Simons, an international consulting engineering company that specializes in the forest products industry.

A key component of this assessment will be the solicitation of background information from key knowledgeable individuals working in the strategic silvicultural planning area in selected countries and regions. As this input will require time, Reid Collins will compensate each key individual for the time spent in providing this input. Specifically, the following assistance is requested:

• Assembly of a short collection of significant published information pertaining to strategic silvicultural planning in their respective country or region. Emphasis should be on summary or review publications that provide overview information

• Preparation of a short, written summary or background report outlining the present situation with respect to strategic silvicultural planning and the planning systems now being used. This paper should be basically limited to each key individual's existing understanding of the present situation in that individual's geographic area rather than on significant new investigations or work by that individual. However, some contact with other key players in each individual's geographic area would be appropriate.

• Follow-up phone consultations as the review develops.

Again, this collection of papers and the background report should address the following two sets of issues:

1. The basic end product strategy that has been incorporated into a given regional silvicultural program. More specifically, what are the common tending regimes that are being applied and what end products are they targeted towards?

2. The nature and extent of macroeconomic modelling of supply and demand used to guide the strategic silvicultural planning process. More specifically:

What approaches and models are available and/or are actually used to estimate or forecast the future domestic supply of wood and forest products? How do these approaches or models account for the range of tree quality and the resulting array of potential end products?

What approaches and models are available and/or are actually used to quantify the potential for alternative silvicultural regimes to augment the domestic supply of wood in terms of volume and value? Again, how do they account for tree quality and end products?

What approaches and models are available and/or are actually used to estimate or forecast the future global supply of wood and forest products? How do these approaches or models account for the range of tree quality and the resulting array of potential end products?

What approaches and models are available and/or are actually used to estimate or forecast future domestic demand for wood and forest products? How do these approaches or models account for the range of tree quality and the resulting array of potential end products?

What approaches and models are available and/or actually used to estimate or forecast future global demand for wood
and forest products? How do these approaches or models account for the range of tree quality and the resulting array of potential end products?

What approaches and models are available and/or are actually used to predict future, domestic and global prices for timber products? These should include simple trend approaches as well as approaches that consider the interaction of domestic and global supply and demand.

What approaches and models are available and/or are actually used to explicitly predict the impact of changes in future domestic wood supply on domestic and global prices for lumber products? These should include simple trend approaches as well as approaches that consider the interaction of domestic and global supply and demand.