designated skid-trail pattern minimized the areas traversed because the bunches were located only on or alongside the trails. The tracked front-end loader-type buncher created a trail that was just wide enough for the skidders but too narrow for the larger conifer bunches. The excavator bunchers created wider roads that could accommodate the skidders and the bunches. The forwarder appeared to cause less disturbance than the skidders because it was the same width as the harvester and logs were carried to roadside. Residual damage also appeared to be related to the number of times the skidder had to re-enter the block, and understorey damage appeared to increase when the skidders had to make a second pass to collect conifer stems after the aspen had been skidded. It appeared that less residual damage occurred when the skidder collected both species during the same entry. Damage to the residuals beside the skid trail was reduced when the bunches were aligned to the skidding direction. This reduced the need to swing the bunch around tight corners at breakout, during skidding, and when aligning the turn with the landing.

Damage to the understorey was reduced at breakout points and along the trail when both aspen and conifer bunches were delimbed prior to skidding. High stumps left beside the trail as rub posts were also effective in deflecting stems around trail-side understorey.

Supervision

From the studies completed to date, the effectiveness of on-site supervision in reducing understorey damage appeared to be related to the complexity of the plan, the experience of the crew, and the willingness of the supervisor to be on site and to supervise. The simpler the plan, the less supervision was required. Plans that required laying bunches in herringbone patterns at specific angles beside the trail, skidding along designated paths, and delimbing bunches in the bush were only carried out properly when the crew understood why the understorey was being saved, if the crew did not think it would lose money, and if a supervisor was on site to enforce the practices. The on-site supervisor guided the crew regarding which residuals needed protecting and which residuals it was practical to protect. For example, the supervisor ensured that areas where understorey was destroyed were used for landings or trails and, that one residual was not saved while two others were damaged.

To date, the study has revealed that when the crew members understood what the trials were trying to achieve and why, they made a conscientious effort to reduce residual damage. They also suggested further operational changes that helped reduce damage to the residuals.

Several of the operating practices used in the study to reduce understorey damage would require acceptance by the regulatory agencies. The use of rub posts required leaving stumps up to 1.5 m high. The Swedish harvester and limbing in the bush left limbs and tops concentrated on the trails where it could be difficult to burn or spread them out, and the recovery of a few sub- or non-merchantable stems in the middle of dense understorey caused more residuals to be destroyed.

Planning

Results of the trials to date suggest that planning, in conjunction with effective implementation, plays a key role in protecting the white-spruce understorey. In the study areas where more intensive planning and layout was carried out, the crews spent less time deciding where trails or landings should go, and less time building roads, trails, and landings. In addition, laying out all trails and landings as early in the operation as possible ensured there were alternative areas to work in when equipment had to be relocated, and that landings were located in areas of reduced understorey, even if this meant increased skidding distances. Planning is also the phase where the costs of harvesting the mature stems must be determined and the increased harvesting costs associated with understorey protection must be balanced with the long-term benefits. For example, understorey protection reduces the need to plant, it helps control the competing vegetation, and it provides valuable habitat for wildlife.

PRELIMINARY CONCLUSIONS

Damage to the white-spruce understorey in mixed-wood stands can be reduced through careful planning, equipment selection, supervision, and the use of special operating techniques.

Careful planning involves:
- Matching equipment to stand conditions.
- Incorporating work practices that are most effective in relation to the amount of supervision available.
- Balancing harvesting costs with the benefits achieved.

Those individuals responsible for layout need to consider understorey protection as early in the planning process as possible. The plan should:
- Recommend the use of the smallest possible mechanical felling equipment possible to fall the stand in one pass, so that a tree is positioned when it is felled or placed in bunches along the skid trail, and a second entry into the stand is avoided.
- Propose a pattern of skid trails that do not have sharp corners and are aligned to the landing, and have trails located and flagged before harvesting starts.
- Locate landings in areas of minimal understory and keep landings as small as possible.

Even the best plan will not reduce understory damage unless its implementation is supervised. Supervisors must explain to the crew what the objective of the plan is and how the plan will be carried out. A supervisor must be on site to ensure that the crew understands and is achieving the desired result, and to modify the plan as required. Supervision of the mixedwood logging areas by regulatory agencies requires an acceptance of practices that may not be currently allowed in conventional logging, i.e. higher stumps left as rub posts, more debris in the block from limbing and topping, and the leaving of standing non- or sub-merchantable trees.

Protection of the white-spruce understory can only occur with the co-operation and active involvement of all individuals: the crew, the supervisors, and the regulatory agencies.
PEST MANAGEMENT TOOLS FOR MANAGING THE BOREAL MIXEDWOOD FOREST

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INTRODUCTION

Mixedwood forest pests create problems for the forest manager. Pest management attempts to solve these problems and improve the productivity of the managed forest over its unmanaged counterpart. In the mixedwood forest, however, special constraints are imposed on these solutions because of geographic, demographic and economic considerations peculiar to this region. The vastness of the area to be managed, the length of rotation ages and the values of products derived from these forests to be used in distant markets dictate that only extremely low-intensity management options are economically justifiable at present.

Management is the process by which one controls or directs a system to achieve some goal. This implies that the manager has some knowledge of how the system functions and how it reacts to any treatments prescribed. The management alternative selected in any situation is equally dependent on the management objective and the knowledge base used to arrive at the decision. Mixed wood forest management decisions are likely to present the manager with a large array of options because of the complexity of the stands being managed. Our contribution to this symposium is to provide a sketch of the information available which may be used to manage pests of forest stands of the mixedwood section of the Canadian boreal forest. To the extent possible, examples from northeastern British Columbia will be used.

The trans-continental boreal forest is characterized by the presence of white and black spruces with balsam fir and jack pine of eastern and central forests giving way to lodgepole pine and subalpine fir in the west (Rowe 1972). Mixed with the coniferous species are the birches and trembling aspen. In the Mixedwood section of this forest (Rowe's B.18a, or boreal white and black spruce in terms of biogeoclimatic terms) the characteristic forest association of upland, well-drained sites is a mixture of trembling aspen, balsam poplar, and white birch. White spruce eventually predominates on these sites as the stands age. The prominence of aspen in this region is due to its remarkable ability to regenerate following disturbance. On drier sites, jack pine or lodgepole pine enter the forest association and is dependent on fire for stand regeneration (Rowe 1972). Most commercial forest operations deal with forests of the well drained and drier sites. Tamarack and black spruce, which are found on the wetter and more northern sites, are also ecologically important in the mixedwood forest section.

Associated with each tree species is a suite of insects and micro-organisms which feed on different tree tissues. Similarly any forest stand is the site in which a variety of plant and animal populations spend all or part of their existence. Whether any one of these organisms is labelled a pest or not depends on the human demand for, and nature of products derived from the stand. There are examples where an organism is considered beneficial in one context and a pest in another. The changing fortunes (from a forestry perspective) of aspen in the mixedwood forest has elevated some insects and diseases previously regarded as benign or not worthy of control to "prime pest status." Indeed, aspen itself is viewed with this ambivalence, even today, depending on whether you are persuaded that softwoods or hardwoods are the raison d'etre of mixedwood forestry. Before designating a species a pest, it is essential that the ecological characteristics of the species and its significance to the management objective for the stand in which it is found are fully appreciated.

Treatments of pest management concerns at previous symposia provided descriptions of pests, their life cycles
and insecticidal or silvicultural control options (Davidson and Prentice, 1968; Hinds, 1985; and Jones et al. 1985). The major focus of these works was on pests of the hardwood component. Important information regarding the effects of pests on stand development was also presented in these reports. The need to integrate this information for use in the mixedwood forest management prescriptions was commented on by Volney (1988a). The major conclusion repeated in all these papers is that insect and disease losses can be minimized if healthy, fully stocked stands, free of disturbances are maintained. The processes underlying this suggest that natural defenses of trees are lowered during disturbance (from wind, frost, drought, mechanical, sun scald, or pest damage) making the trees susceptible to secondary pest attack, growth loss, and mortality. Presumably the process of opening up the stand further weakens trees and contributes to the demise of aspen stands. These conclusions rely on observational studies which have not been rigorously tested by experiment. Further, many of the relationships described have not been quantified.

Despite the shortcomings of the information, managers still have to make decisions. Yet there is a large body of information which needs to be analyzed, interpreted, its utility evaluated and the pertinent conclusions used in improving the knowledge on which forest pest management decisions are made. A tool, which will have a major impact on the way pests are managed and one which is in need of development, is a means to make pest related information easily accessible to managers.

**INFORMATION ON PEST MANAGEMENT:**

The long and short of it

Before any attempt is made to manage pests it is important that the identities of the organism capable of causing damage to a stand are known. Considerable effort has been expended to compile this information. Over the past 53 years, the personnel of the Forest Insect and Disease Survey (F.I.D.S.) of Forestry Canada and their co-operators have put together a fairly complete list of the organisms which feed on trees found in mixedwood forests. Beginning in the early 1950’s this unit has compiled some 6000 records from the Peace River Area of British Columbia. More than half of these records are of species that are not considered pests. Nevertheless these records are important in permitting specialists to identify recent introductions, and in recognizing the potential for secondary pest problems as new forest management techniques are introduced. These records also include listings of beneficial organisms such as predators and parasites.

Approximately 1/5 of the 6000 records were diseases and the rest dealt with insects. The most common of these were foliar pathogens (10 species), stem or branch rusts (5 species), 1 cone rust, 3 canker fungi, and 4 major decay fungi. Among the insect records there were 21 defoliators (15 on conifers), 4 bark beetles, 2 wood borers, 2 terminal weevils, 5 gall midges or aphids, 5 cone insects and 6 beneficial insects. This list is not long. With a little help any forestry practitioner could become acquainted with the signs and symptoms used in the field-diagnosis of these pests. More importantly, the trained practitioner can then become part of pest detection surveys.

There are a number of field guides and manuals available to help in the identification of pests. A series of these have recently been produced by the Northern Forestry Centre. These deal with the diagnosis of damage to trees in the mixedwood forest including: air pollutants and natural stress agents (Malhotra and Blaucel 1980), diseases (Hitatsuka 1987) and insects (Ives and Wong 1988). These manuals treat far more species than would ordinarily be encountered as pests but they serve the purpose of distinguishing pests from benign organisms. These manuals are excellent for use as self-help guides in pest identification. Forest pest leaflets on a wide range of pests are also available from the Pacific Forestry Centre and the Northern Forestry Centre. Both these centres provide an identification service for insect and disease samples originating from forestry concerns in their respective regions. Another set of tools for pest management then, are the collection records for the region and the identification manuals produced largely as a result of this experience.

Besides the identification and determination of pest status of these agents, the F.I.D.S. records serve a second purpose. Because the record spans several years (35-40 years in this area and 53 years in other areas of the mixedwood forest) it is possible to develop spatial and temporal descriptions of outbreak patterns of pests we should be concerned about.

The outbreak patterns for the important insect pests of the aspen component of the mixedwood forest are presented in Figure 1. The most important of these has been the forest tent caterpillar which caused damage during four different intervals in the past 40 years in northeastern British Columbia. Details of the areas affected are presented in the F.I.D.S. annual reports (eg. Wood and Van Sickle 1989) and the Pacific Forestry Centre F.I.D.S. poster presentation at this session. Conditions in other parts of the mixedwood section are reported in the annual reports of the adjacent region (eg. Emond and Cerezke 1989). National summaries are also prepared annually (eg. Moody 1988). Large aspen tortrix outbreaks are more
FIGURE 1: Outbreak histories for the major aspen defoliators of northeastern British Columbia. A) Forest Tent Caterpillar, B) Large Aspen Tortrix, C) Bruce Spanworm

Frequent but of shorter duration, occurring 8 times in the past 40 years. Bruce spanworm outbreaks have occurred 3 times in the past. All stands are not affected by every outbreak and no stand is subject to every outbreak. Thus the distribution of outbreaks within an area is very important in evaluating the significance of each of these outbreaks on individual stand development.

Fewer outbreaks have occurred on the conifer component. Outbreaks of the spruce budworm have been reported mostly north of the mixedwood section of British Columbia. Damage caused by the two-year cycle budworm to mature spruce stands in the three outbreak periods of 1950, 1954-57, and 1962-64 was negligible. Similar comments can be made of damage caused by the larch sawfly in the two outbreak periods in 1962-68 and 1975-77. Problems might be anticipated with the spruce beetle. This species has attacked trees where populations have built up in nearby weakened trees, recently killed trees, or decked logs. Monochamus wood borers have also caused damage to decked logs and salvaged fire-killed logs.

Diseases are probably under-represented in annual surveys because of their characteristic slow spread in stands. Of major concern are the rots. Trunk rot in aspen, red ring rot, brown cubical rot and tomentosus rot in conifers are common. Damage to older trees, including top-kill and radial growth reduction, has been caused by broom rusts of fir and spruce. Stem and gall rusts, though present, have not been major problems in older lodgepole pine stands. Other diseases that are local and patchy in occurrence include spruce cone rust, needle casts, needle rusts, ink spots and shoot blights. Animal damage, damage from frost, and snow breakage have also been reported in the Peace River area of British Columbia.

Perhaps the most important value of this historical information to pest management is that it provides a means of developing some understanding of pest epidemiology and making long-term forecasts. For example, the jack pine budworm outbreaks in forests of Saskatchewan and Manitoba were recently analyzed and long-term and short-term predictors of outbreak occurrence developed (Volney 1988b). The outbreak information used in these analyses was largely collected by the Forest Insect and Disease Survey and its forbearers. Similar analyses are possible with the other major defoliators of the mixedwood section to develop forecasts on the occurrence and extent of damage.

These predictors can be used by forestry concerns to formulate policies and plans for the inevitable outbreaks occurring in the region. If the effects of these pests on the forest resource is to be minimized, this policy will most likely include statements on the priority of stands to be harvested. These priorities would be developed from a consideration the probable losses from pests in addition to all the other considerations normally used in developing harvesting schedules.
Knowing the long-term and regional expectations of damage does not provide the manager with the detailed information required to evaluate the hazard for specific stands. Hazard rating stands in the mixedwood forest is in its infancy. However, several components of this tool have been developed for a variety of pests. For example, pheromone trapping techniques are being calibrated to permit the prediction of spruce budworm defoliation in spruce stands (Sanders 1988). The attractants that would permit monitoring all the major aspen defoliators in the mixedwood forest of northeastern British Columbia have been at least partially identified. Synthetic pheromone preparations for the forest tent caterpillar are being tested, for detection purposes, having been identified in 1980 by Chisholm et al. (1980). A pheromone component of the large aspen tortrix has been reported (Weatherston et al. 1976). A sex attractant for the Bruce spanworm moth has been characterized (Underhill et al. 1987). Attractants for the jack pine budworm, a pest of eastern forests of the mixedwood section, have also been field tested (Butterworth and Silk 1989). These tools could be developed in concert with the traditional detection surveys to provide improved site-specific and short-term forecasts of population increases and potential for damage to the stand.

Less information is available on the effect of pests in reducing stand yields. Nevertheless, there are means of predicting the impact of pests on stand productivity from present and future outbreaks. An example of the effect of a forest tent caterpillar outbreak on the development of young aspen stands was presented at the last mixedwood symposium (Volney 1988). Based on the modeling efforts of Matson and Addy (1975) the net effect of one outbreak was a 25% reduction in the accumulated stem wood biomass and a permanent reduction of the capacity of the stand to realize its maximum yield. Predictions of pest impacts can be adjusted for local conditions. The impact information now being acquired by F.I.D.S. personnel in this region together with other forest inventory data would ultimately permit predictions of this sort to be made. The important point is that repeated outbreaks have considerable impact on the productivity of stands.

What can be done about forecasts of unacceptably high pest populations? Perhaps the single most effective treatment tool available to the forest manager is modification of harvest schedules to harvest high-risk stands before they sustain unacceptable levels of pest damage. This technique has the appeal that there is no, or very little, increased cost in its application and there is little increased environmental risk in its implementation. The disadvantage is if the proportion of stands in the high-risk category is large, it will be impossible to harvest all stands requiring treatment without seriously affecting future timber supplies. When this occurs, other techniques have to be resorted to. Direct control of defoliators has been practiced in Canada for several years. Presently, the favored control technique for the forest tent caterpillar on large areas is to aerially apply a biological insecticide, Bacillus thuringiensis (or B.t.). Although not specifically registered for the large aspen tortrix, this insecticide is known to be effective in reducing damage from the large aspen tortrix (Holsten and Hard 1985). (As the registration status of individual preparations change it is best to determine which materials are registered for specific pests on each host for a particular use by checking with the Pesticides Directorate of Agriculture Canada and the provincial agencies which regulate pesticide use in the jurisdiction concerned.)

In some situations a do-nothing option may be valid. More than a dozen parasites of large aspen tortrix along with disease and weather usually cause collapse within three years. Because the larvae feed early in the spring, the trees resurface in the same year usually with little tree mortality. The impact on growth and risk of attack from secondary pests may be sufficiently low to be acceptable at current levels of management. Impacts on aesthetics or public concerns may be greater.

Silvicultural treatments to mitigate pest conditions in mixedwood stands have not been developed. Some silvicultural treatments may exacerbate pest effects. There is considerable experience to suggest that heavy thinning of aspen stands to release spruce may not achieve the desired result. Young white spruce trees are extremely susceptible to attack by the white pine weevil, so much so that it is called the spruce weevil in this western province. The result of opening up stands prematurely can, therefore, be quite devastating on understory white spruce. This could be a potential problem in the Peace River region as forest management intensifies. Diseases which are now benign in the region, such as septoria canker, may become a problem with the introduction of hybrid and exotic poplars (Davidson and Prentice 1968).

PEST MANAGEMENT AND EXPERT SYSTEMS

A self-improving solution?

Pests create a bewildering array of concerns for the forest manager who often feels ill-equipped to make decisions regarding pest management. Further, there is often a sense that the information available is incomplete or unavailable, despite the enormous amount of effort expended by specialists in the past. To further exacerbate the manager's predicament, pest management specialists may not be available to provide the individual attention required to
satisfactorily design and implement pest management protocols for the land base being managed. One tool developed to assist resource managers is the pest management system.

Forest pest management should be an integral part of integrated resource management. As such, the decisions to acquire information about pest conditions, to treat stands and to evaluate treatments have to be compared to the competing opportunities for the funds required to perform all activities of the management agency. A crucial concern in this regard is how the information required to manage pests is to be acquired and utilized. Pest management systems perform these functions. A typical system might consist of procedures to: monitor pest conditions in individual stands, forecast the likelihood of damage from the pest condition reports, decide on a course of action, and to monitor and evaluate the results of the prescribed action. These procedures are based on an understanding of the reciprocal interactions among pest populations, dynamics, stand dynamics, and treatment effects. The response of the pest populations and stand productivity to the various treatment options are evaluated using econometric tools to obtain benefit/cost ratios which can be used to select among the options available to the manager. Depending on the complexity of the situation involved, this system may be automated to varying degrees using computer-based models in addition to other decision support systems used to collect, process, and display information required to make decisions in forest management.

Despite the development of decision support systems and pest management systems for several major forest pests in other regions of North America, several of the tools were not applied (Coulson et al. 1989). One of the major causes for this was the difficulty of handling incomplete information. This difficulty is compounded by the scarcity of specialists to assess the utility of opinions and evaluate the consequences of using "best guesses" which experts often are forced to use when faced with inadequate information. Systems are now being developed to overcome these deficiencies (Coulson et al. 1989).

Known as knowledge-based systems, or more commonly, "expert systems", these tools attempt to simulate the reasoning used by experts in dealing with the management of complex enterprises. An expert system contains a "knowledge base" in which all knowledge available on a subject is coded in a fashion that makes it accessible to an "inference engine." This inference engine processes the information, updates the knowledge base with current information and produces a recommendation for the manager's scrutiny. The manager has the option of obtaining statements on how the system arrived at a particular recommendation. A characteristic of expert systems is that the information fed back to the system as a result of action can be used to modify the knowledge base. Thus the experience gained from implementing any action on the forest is immediately incorporated to improve the knowledge base. This is analogous to learning from experience, and is critical to improving our understanding of the system being managed.

Expert systems designed for forest pest management will probably have several peripheral systems to assist in automating the decision making process as well as managing and acquiring the data sets. In situations where many individual stands are being managed, a geographic information system would become an important component of the expert system. Other utilities would include connection management systems for managing information flow among several distributed work sites, data base management systems for data management, and various output devices to display results.

A final feature of these systems is that they can be configured to address the questions asked by managers at several levels of the management hierarchy. Thus the district forester, the regional resource management officer, and the chief forester of an agency can utilize the same information to make decisions at different administrative levels.

The costs, constraints, and benefits involved in expert system development for forest pest management in conditions such as those of the northern mixedwood forest were discussed recently (Volney 1989). Expert systems of this sort are expected to take six to eight person years to develop provided that the necessary experts can be assembled and persuaded to participate. In addition to the fuller utilization of available information in making decisions, expert systems offer an opportunity to overcome some of the training and technology transfer problems the older systems encountered in their implementation. Of equal importance, they will not replace human experts but will serve to assist them in focusing on the more difficult pest management problems.
CONCLUSIONS

The tools required to manage pests of the mixedwood forests are the ability to: identify pests, predict the threat pests present to achieving forest management goals, evaluate the need for treatment, select the best treatment warranted; and evaluate the results of treatments. How good these tools are depends on the skill of the manager in applying what is available. All tools (be they pest identification, pest conditions assessment, predictors of spatial and temporal characteristics of outbreaks, hazard rating methods, or impact models) need improvement. The real challenge is to improve them in a manner which will result in the greatest improvement of management results for the effort expended. A means of improving our skills of managing pests, the information about managing pests, and of improving our understanding of the deficiencies of the knowledge-base may be provided by expert systems.

REFERENCES


INTEGRATED USE IN MIXEDWOOD FORESTS – A CHALLENGE

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ABSTRACT

The mixedwood forest in northern Canada and the aspen ecosystem in the western U.S. have many similar values. Both types are excellent for multiple- or integrated-uses. They have a moderate but increasing value for wood products; they furnish excellent habitat for many wildlife species; they have abundant forage for livestock and big game; they provide superb watershed protection, especially on steep mountain catchments; and, they have aesthetic appeal, particularly on mountainous landscapes in a mosaic with meadows, pure stands of conifers, and pure stands of aspen. In the United States no single value dominates and controls ecosystem management. Integrated management is practiced. Active management is necessary to retain aspen on most sites because it is seral and will give way to more tolerant conifers if protected long enough from catastrophic events, especially fire. Management of the aspen and the mixedwood systems for their multiple values is preferred. Good silviculture and multiple-use management are quite compatible. The dynamic and resilient nature of these ecosystems facilitates management.

SIMILARITIES AND DIFFERENCES

The mixedwood section of Canada has many similarities with the aspen type of the western United States, with which I am familiar. These similarities dominate the following discussion on integrated use. However, there are major differences between the aspen type in the western U.S. and your mixedwood complex. These differences, both socioeconomic and ecologic, must be kept in mind if application of the U.S. multiple-use experience is to be successfully applied to your vast mixedwood system.

SOME SIMILARITIES

- Aspen originates after some major disturbance, usually fire, and is successional to conifers on most sites.
- Abundant understory vegetation grows under aspen; sparse understory under conifers.
- Much of the land in the mixedwood and in the montane aspen is remote and relatively inaccessible. Construction of expensive roads is necessary to put a moderately valued forest under management for wood products.
- Wild ungulates are an important part of the ecosystem.
- Relatively low or no value of the aspen for wood fiber in many areas; but there is a rapidly increasing interest in its utilization.
- Most of these forested lands are publicly owned and managed.

SOME DIFFERENCES

- Succession from aspen to high-value white spruce in Canada but succession to valueless sub-alpine fir on many sites in the U.S.
- A primary value and use of the aspen type in the western U.S. is livestock grazing; much less so in the mixedwoods of Canada.
- Mountainous terrain throughout much of the aspen type in the western U.S.
- There is a greater emphasis on recreation and aesthetic values in the western U.S. aspen ecosystem because of the mountainous terrain and its proximity to large population centers.
A smaller percentage of people in western U.S. communities within the aspen area are dependent upon forest industries for their livelihood.

The U.S. aspen ecosystem, being further south, mountainous, and with a broad array of sites, has a greater number of tree and understory plant species than do equally large areas of Canada's mixedwoods.

Public ownership and management of forests is much different in our two countries. The U.S. does not have corporate long-term leases for timber management. Each timber sale is bid as a separate entity.

THE CHALLENGE

The challenge to integrated management in the mixedwood type of Canada will require some of the same changes in thinking and attitudes on the part of silviculturists and timber managers as was required in recent decades in the United States. On large areas of forested public lands in the U.S., the value of wood products has, with some reluctance, been given a secondary or tertiary position behind other wildland uses. The silviculturist has had to become a team player alongside wildlife, range, and watershed managers, recreation specialists, landscape architects, and archaeologists. No longer is the traditional forester “in charge”; no longer do wood product values and the silvicultural system control management. For better or worse, the spotted owl seems to hold equal place with timber from coastal Douglas-fir, and aesthetics and recreation with flakeboard from Colorado aspen. I’m not sure that all of this is “good”; it has had economic impacts. But it has re-focused the vision of many “timber beasts” who saw the forest only as a wood factory.

Today, on public lands, the best leaders are those who are able to integrate the multiple values and uses of the wildlands in their charge. This is the first facet of your challenge for integrated use in the mixedwood—to refocus as necessary the vision and emphasis of forest land managers. The forest is more than trees. A second facet of the challenge is one of education and salesmanship. Managers of wildlands, both public and private, must have public support for major policy decisions and management actions. The managers who have a thorough understanding of all the values of the mixedwood forest must transmit that knowledge to their colleagues, employers, constituents and the public. Then, when integrated use decisions or proposals are made, they will continue to be supported as professional and responsible resource managers. Special interest groups must be considered. On public lands in particular, public involvement becomes part of the policy and decision making process. On private lands, the manager must educate the rest of the corporate structure. In effect, the manager becomes a salesman for balanced (integrated) resource management on forested land. Resource values, both present and future, must be considered. This is the second facet—to educate and sell the integrated management program within the organization and to the public.

The third facet to this challenge is one of prediction. We must look into the crystal ball and accurately determine what the market and society is going to demand from this mixedwood system in the next century.

If we assume that transportation will continue to be relatively inexpensive and that much of the world will continue its present standard of living, then we can predict that the economy of this mixedwood area will grow and prosper during the next 30 to 70 years. If the above assumptions do not hold, the mixedwood might again become as isolated from the food producing and heavily populated parts of the world as it was 30 to 70 years ago.

On the other hand, the global warming that has been predicted by some may make this area the breadbasket of North America within a century.

I prefer to be optimistic; that transportation will remain cheap, and that a significant portion of the world’s population will enjoy a high standard of living with considerable leisure time activities. If my prediction holds, then the mixedwood system of Canada will continue to grow in importance as a supplier of fiber (cellulose), outdoor recreation, and, as a spin-off from the latter, red meat and fish.

I further predict that advanced wood products technology is going to make maximum cellulose production from the mixedwoods more important than management for any given tree species. Optimum habitat for a diversity of wildlife, especially large ungulates, will be equally considered with good production in silvicultural prescriptions. Aesthetics and watershed values will grow in importance as well.

If wood production, wildlife production, recreation, aesthetics, and watershed (especially as it pertains to aquatic habitats) hold equal importance for your future wildland managers, then they will be facing the same challenges as the present managers of aspen lands in the Lake States and western U.S. It is based upon these predictions that I make my suggestions for integrated multiple use management of the mixedwood.
RECOMMENDATIONS


Integrated use comes with tradeoffs and costs. Hopefully, any lost timber production and lost efficiency in harvesting will be more than offset by enhancement of other values and increased returns from other resources in this mixedwood system.

RECREATION AND AESTHETICS

Where a satisfactory road network is present, particularly on hilly or mountainous terrain, a mixed forest of hardwoods and conifers provides intangible returns in the form of recreation and aesthetics. Management activities in this setting in the long run can be used to enhance rather than detract from aesthetic values.

Clear-cuts may be used to create variety in dense and continuous stands. The clear-cuts should be small, irregularly shaped, and fit into the landscape. Minimize the impacted area that can be seen from any given point on the clear-cut. Make sure that all operations appear neat and organized with no unsightly debris and litter. Properly treat skid trails and landings as the operation progresses. Roads should fit into the landscape. Don’t harvest adjacent to a clear-cut until it has had sufficient time to regain a forested appearance. Provide for permanent scenic vistas and keep them open. Provide for a diversity in forest types, species mixes, and size classes on the landscape (Peralta 1977).

Aspen forests are great for dispersed recreation. Aspen also is good cover on ski areas. But this species does not tolerate concentrated human activity, as in developed campgrounds (Hinds 1976). Place your campgrounds in conifers or at least in a mix of conifers and hardwoods.

WATERSHED VALUES

The watershed manager is concerned with water quality and yields. If erosion from the forest site reaches the stream, it becomes sediment, which drastically reduces water quality. The undisturbed mixedwood forest provides excellent soil protection; overland flow and erosion are minimal. However, clear-cut harvesting, heavy grazing, road and firebreak construction, and fire all have the potential of barring sufficient mineral soil to permit accelerated erosion. Fortunately, in much of the mixedwood, the soil barely through these disturbances again is quickly protected within a year or two with a cover of aspen, shrubs, and herbaceous plants. Nevertheless, the manger should strive to maintain at least 65% soil cover and minimal sized bare soil openings on erosion susceptible sites (Marston 1951; Meeuwig 1970). The vegetation in and adjacent to stream channels should not be disturbed. And, roads, skid trails, landings, and similar areas should be treated so they will not erode.

Timber harvesting will increase water yields. In the western U.S., clear-cuts in aspen yield 10 to 15 cm more water than the uncut forest (Johnston et al. 1969). Regrowth of aspen suckers is rapid; and water consumption by the regenerating forest should negate the increased yields within a decade after harvest. Conifers use more water than aspen. They also reoccupy a site more slowly after harvesting. Hence, clear-cutting a conifer stand will have a greater effect on water yields for a longer period of time than will clear-cutting an aspen stand.

FORAGE

The aspen type in the western U.S. commonly produces 1,100 to 2,250 kg/ha of undergrowth each year (Houston 1954). Much of this production is a palatable and highly nutritious forage that is heavily utilized by both wild and domestic ungulates. In stark contrast, conifers on similar sites yield only a fifth as much forage. As conifers invade and take over a site, forage production rapidly decreases.

Clear-cutting or fire in the aspen or mixed aspen-conifer forest results in a significant increase in undergrowth production that is even more palatable and attractive to ungulates (Bartos and Mueggler 1982; Brown and DeBye, in press). In the western U.S. a common problem is overuse of the forage resource. Livestock grazing or heavy use by big game can destroy aspen regeneration, even when a dense stand of suckers comes up after clear-cutting or fire. This is especially true on small clear-cuts or burns that attract ungulates to the heavy crop of palatable forage. Careful grazing management, especially of sheep, is necessary for at least 3 to 5 years after suckers arise so they will outgrow the reach of browsing livestock. Concentrations of big game, especially elk, can be very destructive to aspen regeneration. Most damage is done to aspen on winter and spring range. Herd size control by hunting is the most satisfactory answer if aspen is to be retained on heavily used ranges.
Several papers in last year’s symposium proceedings (Samoil 1988) stated that the undergrowth of grasses and shrubs in the mixedwood forest is a severe competitor for conifer regeneration; inferred that it had no value and was only a problem; and recommended its control with herbicides. I recommend that the value of the undergrowth as wild and/or domestic ungulate forage be seriously considered.

WILDLIFE

A mixed forest of aspen, other hardwoods, and conifers contains a diversity of habitats and, as a result, many species of wildlife. The mixedwood fits that description. In the somewhat similar aspen ecosystem of the western U.S., there are about 135 species of birds and 56 species of mammals. Among them are several important game species (elk, moose, deer, and three species of grouse). Active management of that ecosystem, just as active management of the mixedwood system can be used to enhance wildlife habitat. Clear-cutting or burning mature stands of aspen benefits several species; including moose, elk, deer, ruffed grouse, and snowshoe hare; by triggering the production of more forage and a denser stand structure. Fire or clear-cutting also retards succession and retains the seral hardwood component in these systems. However, the mature and over-mature aspen forest is preferred habitat for some other species, such as bears and cavity nesting birds. Still other species, such as pine martens and red squirrels, do best in pure conifer stands. Healthy populations of many wildlife species are encouraged if the manager maintains a mosaic of habitats consisting of an array of age and size classes, of mixed stands, and of pure stands of both conifers and hardwoods. More specific recommendations are made for habitat management to favor maximum populations of individual species in DeByle (1985).

GENERAL RECOMMENDATIONS

While managing the mixedwood system for wood products, the other values and resources as a group will be best served if:

1. Clear-cuts are kept as small as practical. Instead of a minimum of 50 hectares, as now recommended, perhaps that ought to be the maximum size.

2. The clear-cuts are irregular in shape and fit into the landscape. Roads should also fit the landscape.

3. The two-stage harvesting scenario proposed by Brace and Bella (1988) be used to maximize production of both aspen and spruce in the long term. This will also ensure the perpetuation of a maximum diversity of wildlife habitats in conifers, in aspen, and in mixed conifers and aspen.

4. The mixed forest is encouraged. Forest succession is used, not fought.

5. Thinning is done only in conifer stands; the aspen will thin itself at no cost. Besides, those dense young sucker stands of aspen are excellent habitat for several wildlife species.

6. Herbicides are used only where absolutely necessary. They, like thinning, become a long-term investment with minimal return. Herbicides may do a good job of releasing conifers, but they also alter a forage-rich understory, kill potentially valuable hardwoods, and alter or destroy wildlife habitat.

7. Incentives are provided entrepreneurs to develop all values and resources in the mixedwood.

CONCLUSIONS

Aspen and aspen-conifer forests can be successfully managed for several values simultaneously. Often a treatment prescribes for enhancement of one value will enhance others as well. This very dynamic system is also quite forgiving of management errors. Even where conifers are the preferred wood producing species, a mix with aspen provides catastrophic insurance. Fire, extensive blow-down, or insect outbreaks may destroy the conifers, but with an adequate distribution of aspen in the stand, the aspen will rapidly regenerate and occupy the site. Conifers will come in again later.

I have never felt that management for multiple returns from the aspen ecosystem need be a particularly difficult challenge from the physical or biological point of view. The same applies to the aspen-conifer forest in the mixedwood. The harvest operation provides the tool, without cost, to manage this system for wildlife species that we may wish to emphasize, for enhanced forage production for either wild or domestic ungulates, for increased water yields, and even for aesthetics. Moderate sized clear-cuts that blend into the natural landscape need not be offensive intrusions by man. The road system can provide access for recreation, fishing, or hunting.
When all resource values, both tangible and intangible, are summed, I would suspect that the mixed aspen and conifer forest on these sites will be more valuable in the next one or two decades than extensive stands of white spruce. So, merge the mix, look at the positive values afforded by the hardwoods, and try to utilize the mix of products and intangibles that this system has to offer. In so doing, the challenge will become an opportunity.

There are many potential conflicts that need to be resolved to permit successful management of this multiple valued system. Recognition of these values on the part of the managers, education of the public to assure them that you are truly managing the ecosystem with all values considered, and public involvement in the decision making process, are all necessary.

REFERENCES


SOME THOUGHTS ON THE ECONOMICS
OF MIXEDWOOD MANAGEMENT

C.V. PEARCE
Consultant, Vancouver, B.C.

ABSTRACT
The choice of aspen (Populus tremuloides) versus spruce (Picea glauca) as crop tree species, and the most efficient treatments for regenerating these species are controversial topics in the management of mixedwood stands in the boreal forest. This analysis uses a simple technique to illustrate that a 10 to 20 fold greater product value is necessary for spruce products to justify establishing spruce plantations rather than accepting inexpensive, natural aspen regeneration on medium sites. Aspen management also provides wood supply during a predicted shortage period in 50 to 120 years.

INTRODUCTION
Thank you to the organizing committee for the opportunity to contribute to this symposium, and to Dr. Petersen for the introduction. As my biography indicates I am neither a well-established economist nor a silviculturist of the boreal forest. So what am I doing making this presentation? The organizing committee asked that I provide an analysis of hardwood versus softwood regeneration in boreal mixedwood stands that would be understandable to operational foresters. They stressed the need to review the main economic issues in terms that would be familiar to this group.

The vigorous natural suckering of aspen after harvesting mixedwood boreal forest sites provides inexpensive regeneration of this species, but it creates severe competition and thus high reforestation costs when establishing spruce plantations. Preference for spruce could be justified in the past because of the lack of processing technology for aspen products. Recent developments in this technology now provide opportunities to produce high value aspen products. These changes have made it difficult to follow the traditional preference for spruce, but left uncertainty about how reliable and acceptable natural aspen regeneration is. This analysis is designed to provide some food for thought for those of you facing this problem.

I will first clarify the perspective of this analysis and then define the management options that are analyzed. This is followed by a description of the analysis process and the data used. The results of the analysis and comments on its interpretation follow. I will end with some cautions on extrapolating these results.

Perspective of the Analysis
This analysis has been completed for publicly owned land in the boreal forest area of British Columbia. In this province legislation requires that every area that is harvested must be regenerated to meet defined standards. There is no question whether or not regeneration costs should be incurred; the relevant questions are:

a) what should the regeneration standards be for specific sites, and,
b) what are the least-cost methods of achieving these standards?

Site-specific regeneration standards are based on management objectives. This analysis has been completed for medium productivity sites in the boreal forest which support a mixed stand of aspen and spruce or pure Aspen before harvest. Timber products are assumed to be the primary management objective for these sites. Comments on the impacts of the regeneration options on non-timber resources will be made.

Management Options
The organizing committee asked that an evaluation of pure spruce, pure aspen and mixedwood options be provided. Table 1 describes the regeneration treatments that have been analyzed for each option. The high yield options have been adapted from those proposed by Day and Bell (1988) during the symposium last year in Alberta. I have attempted to keep these regimes similar to the ones presented by Dr. Navaratil earlier in this symposium to avoid confusion.

Specific treatment methods have not been defined because these decisions are site specific and in some cases, such as site preparation for the ‘assisted natural aspen’
TABLE 1. Management Options

<table>
<thead>
<tr>
<th>Species to Regenerate</th>
<th>Treatment Name</th>
<th>Reforestation Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural</td>
<td>Surveys*</td>
</tr>
<tr>
<td>Pure aspen</td>
<td>Assisted</td>
<td>Site prepare; surveys</td>
</tr>
<tr>
<td></td>
<td>natural</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High yield</td>
<td>Space; 2 thinnings; surveys</td>
</tr>
<tr>
<td>Pure spruce</td>
<td>Raw planting</td>
<td>Plant; surveys</td>
</tr>
<tr>
<td></td>
<td>Optimistic</td>
<td>Site prepare; plant; surveys</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Site prepare; plant; brush; surveys</td>
</tr>
<tr>
<td></td>
<td>Aggressive</td>
<td>Site prepare; plant; brush 2 times; surveys</td>
</tr>
<tr>
<td></td>
<td>High yield</td>
<td>Site prepare; plant; brush 2 times; space; 2 thinnings; surveys</td>
</tr>
<tr>
<td>Mixedwood</td>
<td>Understory protection</td>
<td>Careful logging; surveys</td>
</tr>
<tr>
<td></td>
<td>Underplanting</td>
<td>Underplant spruce; careful logging; surveys</td>
</tr>
</tbody>
</table>

* Stocking and free-growing surveys

option, the most effective treatment is not yet known. Costs of a variety of treatments are very similar thus this lack of definition does not greatly compromise the accuracy of the analysis.

The 'understory protection' option for mixedwood management assumes there is an adequate understory of natural spruce. Although the literature does not include many trials where spruce has been planted under an aspen stand, and there are stories of poor success with this treatment on an operational basis (E.B.Petersen, personal communications) I have included this option to illustrate its relative value if the appropriate treatments are identified.

ANALYSIS

Decision Criteria

Conventional economic analyses have used the discounted cash-flow approach. This requires knowledge of regeneration costs, growth and yield patterns, future harvesting costs, product values and the appropriate discount rate for the period of the analysis. The long time period between the outlay of reforestation costs and the returns from harvesting the stand make it very difficult to define the harvest costs and product values. The appropriate discount rate is also difficult to define over such long periods. These uncertainties make it possible to question the results of a conventional economic analysis if they are not consistent with common perceptions.

A simpler criteria which does not include future product values, harvesting costs or a discount rate is the regeneration cost per volume of wood produced. Options having lower regeneration costs per cubic metre of volume are preferred. As Table 2 illustrates, although this criteria is easy to understand and interpret, it does not incorporate the impacts of differences in the rotation ages of options. Longer rotations with more volume production have lower costs per cubic meter of growth with this criteria.

This can be overcome by discounting the volume in the same way the net product value is discounted in a conventional analysis, (Pearse et al., 1986) or by calculat-
TABLE 2. Example of decision criteria

<table>
<thead>
<tr>
<th>Example</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reforestation cost ($/ha)</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Volume (m³/ha)</td>
<td>315</td>
<td>540</td>
</tr>
<tr>
<td>Rotation age (years)</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>Cost/m³</td>
<td>$1.16</td>
<td>$0.90</td>
</tr>
<tr>
<td>Mean Annual Increment (m³/ha/yr)</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Cost/m³ MAI</td>
<td>$111</td>
<td>$111</td>
</tr>
</tbody>
</table>

ing the annual production or the mean annual increment for the option. The latter represents the regeneration cost required to create a cubic meter of wood annually. This criteria most accurately represents the silvicultural decision when the perspectives of timber supply from a forest area are considered (assuming no supply constraints due to age class distribution).

Since the question posed in this analysis is not an investment question of 'Should we practice reforestation on these sites?' but rather the question of 'What are the best reforestation standards in the boreal forest?' we are free to use alternative decision criteria. The cost per cubic meter of mean annual increment can be calculated with only reforestation costs and yield data which are relatively well documented. The results can be used to indicate the difference in the net value of the product that would be required to offset differences in reforestation costs.

Data

Lack of data is the most common reason given for not attempting to analyze forestry decisions. This is especially true in the frontier areas of this province. However, let’s remember that these decisions must be made. Even if we’re doing it in our heads, some form of data has to be used. The analysis process documents the data that is used and ensures our calculations are correct.

Reforestation and stand tending costs

Actual treatment costs incurred in local silvicultural programs during 1988 were used in this analysis. Table 3 lists these costs for each option. On-site and supervision costs are included but overhead is not. The planting cost includes the cost of growing and transporting the seedlings.

Successfully establishing spruce plantations in boreal forest conditions is a relatively risky silvicultural task. Low survival and poor growth often occur on these sites. Additional regeneration costs retreatments are included for the plantation options to account for these risks.

Growth and Yield

Unfortunately there will not be a separate presentation on the relative growth and yield of aspen, conifer and mixedwood stands in boreal conditions. This topic deserves a presentation of its own. A summary of various sources is provided in Table 4. A 'base case' analysis is provided using 'middle of the road' values. Sensitivity analysis will test the impacts of assuming relatively high spruce and low aspen yields.

Results

Table 3 provides a summary of the calculated reforestation cost per cubic meter of mean annual increment using the base case yield projections for the management options that were analyzed. In the least cost scenario for spruce establishment, where planting without site preparation would be successful, this option must produce a net product value that is approximately 20 times ($195/$9) greater than the cheap aspen natural regeneration option in order to justify preferring spruce over aspen. Since it costs 20 times more to produce the same annual volume growth, the spruce volume must be worth approximately 20 times more than aspen to justify the increased cost. This difference will be referred to as the breakeven net product value differential in this analysis.

It is important to recognize the high risks of failure with the least cost option. The breakeven net product value differential must leap to approximately 40 times if the high probability of failure with the planting only option is considered, and retreatment costs are included in the analysis. When retreatment costs are included in the analysis the high yield spruce option becomes more favourable because of its high success rate and high volume production. This result supports the operational perspective that if you’re going to establish spruce on these sites you had best plan to manage it aggressively to get maximum production for your costs.

This analysis indicates the mixedwood options should be promoted over the pure spruce options if spruce regeneration is available and preferred. It should be stressed that
TABLE 3. Calculation of reforestation costs per cubic meter of mean annual increment

<table>
<thead>
<tr>
<th>Option</th>
<th>Reforestation Cost ($/ha)</th>
<th>Rotation Age* (yr)</th>
<th>MAI (m³/ha/yr)</th>
<th>$/m² MAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure aspen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural</td>
<td>40</td>
<td>75</td>
<td>4.5</td>
<td>9</td>
</tr>
<tr>
<td>Assisted</td>
<td>340</td>
<td>75</td>
<td>4.2</td>
<td>81</td>
</tr>
<tr>
<td>High yield</td>
<td>740</td>
<td>40</td>
<td>6.0</td>
<td>123</td>
</tr>
<tr>
<td>Pure spruce**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant only</td>
<td>810</td>
<td>130</td>
<td>4.2</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>1600-1800</td>
<td>130</td>
<td>4.2</td>
<td>380-434</td>
</tr>
<tr>
<td>Optimistic</td>
<td>1110</td>
<td>120</td>
<td>4.3</td>
<td>257</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>120</td>
<td>4.3</td>
<td>372</td>
</tr>
<tr>
<td>Average</td>
<td>1410</td>
<td>120</td>
<td>4.5</td>
<td>313</td>
</tr>
<tr>
<td></td>
<td>1910</td>
<td>120</td>
<td>4.5</td>
<td>424</td>
</tr>
<tr>
<td>Aggressive</td>
<td>1710</td>
<td>120</td>
<td>4.5</td>
<td>380</td>
</tr>
<tr>
<td>High yield</td>
<td>2310</td>
<td>70</td>
<td>6.8</td>
<td>288-385</td>
</tr>
<tr>
<td>Mixedwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understory</td>
<td>490</td>
<td>120</td>
<td>8</td>
<td>61</td>
</tr>
<tr>
<td>protection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underplanting</td>
<td>1300</td>
<td>60/120</td>
<td>8</td>
<td>163</td>
</tr>
</tbody>
</table>

* Rotation ages based on maximum volume production and piece size were used in this analysis. Regeneration delays are included in this rotation age.

** The impact of increased reforestation costs to account for plantation failures are shown in the second line of the Plant only and Optimistic options.

realizing the relatively low regeneration costs and high yields used here will require improvements in existing operational practices.

Since the data for these analyses is very preliminary, and the results do not support traditional practices, it is important to evaluate ranges of outcomes, or "What if...?" scenarios. Table 5 compares the results of the previous analysis with a scenario where the lowest aspen yields and the highest spruce yields are achieved. In this view of the future the break-even net product value differential for spruce is reduced to 16 times that of aspen, and all spruce plantation options have similar outcomes. The high yield spruce option should still be preferred because of its shorter rotation and the probability of achieving larger piece sizes.

To complete this analysis it is important to question what the likelihood is that spruce products will be 10 to 20 times more valuable than aspen in the future. First let's review current product values. Table 6 summarizes this information. Note that in locations where processing facilities exist to manufacture products from both species there is at best a 2 fold difference in the value of raw logs. This relationship doesn't improve much when you compare the value of finished products. Remember: aspen is a high quality fibre that can be used to produce high value paper and composite board products.

Predicting future values is difficult if not foolish. There is no doubt that product values will increase, but will the increase be different for spruce versus aspen? Perhaps
TABLE 4. Summary of yield projections for medium sites in Canadian boreal forests

<table>
<thead>
<tr>
<th>Species</th>
<th>Data source</th>
<th>Rotation Age (years)</th>
<th>Merchantable Volume (m³/ha)</th>
<th>Mean annual Increment (m³/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>Saskatchewan</td>
<td>65</td>
<td>175-196</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Ontario</td>
<td>55</td>
<td>271</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>B.C.</td>
<td>80</td>
<td>213</td>
<td>2.7</td>
</tr>
<tr>
<td>Spruce</td>
<td>Saskatchewan</td>
<td>75</td>
<td>230-315</td>
<td>3.1-4.5</td>
</tr>
<tr>
<td></td>
<td>B.C.</td>
<td>110</td>
<td>280-455</td>
<td>2.5-4.2</td>
</tr>
<tr>
<td></td>
<td>Managed stand</td>
<td>50</td>
<td>330</td>
<td>2.9</td>
</tr>
<tr>
<td>Mixedwood</td>
<td>Ontario</td>
<td>120</td>
<td>321</td>
<td>3.6-5.4</td>
</tr>
<tr>
<td></td>
<td>B.C.</td>
<td>120</td>
<td>321</td>
<td>2.7</td>
</tr>
</tbody>
</table>

Note: These values are greatly influenced by differences in utilization standards and rotation age definitions. This information is only intended to provide the reader with a perspective on the ranges in this data.

SOURCES:


British Columbia: Jim Goudie, Research Branch, B.C. Forest Service, personal communication.


the best approach is to compare the cost of hardwood and softwood fibre in countries where spruce and aspen are grown and processed, and which have already experienced fibre supply shortages and increases in prices. Table 7 shows the similarity in fibre costs for hardwood and softwood species in Sweden and Finland.

This information indicates there is little reason to believe there will be large enough differences between aspen and spruce product values to justify incurring the very high and risky costs of establishing spruce plantations on medium sites where natural aspen regeneration is vigorous and well distributed.
### TABLE 5. Comparison of base case and high spruce/low aspen yield scenarios listed from lowest to highest cost/m³ MAI.

<table>
<thead>
<tr>
<th>Base Case Scenario Option</th>
<th>Cost/m³ MAI</th>
<th>Breakeven Value</th>
<th>Product Differential</th>
<th>High Spruce/Low Aspen Cost/m³ MAI</th>
<th>Yield Scenario Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural aspen</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>16</td>
<td>Natural aspen</td>
</tr>
<tr>
<td>Assisted aspen</td>
<td>81</td>
<td>-</td>
<td>-</td>
<td>123</td>
<td>High yield aspen</td>
</tr>
<tr>
<td>High yield aspen</td>
<td>123</td>
<td>-</td>
<td>-</td>
<td>146</td>
<td>Assisted aspen</td>
</tr>
<tr>
<td>High yield spruce</td>
<td>288-385</td>
<td>32-43*</td>
<td>16</td>
<td>261</td>
<td>Average spruce</td>
</tr>
<tr>
<td>Optimistic spruce</td>
<td>372</td>
<td>41</td>
<td>16-17</td>
<td>256-278</td>
<td>Optimistic spruce</td>
</tr>
<tr>
<td>Aggressive spruce</td>
<td>380</td>
<td>42</td>
<td>18</td>
<td>285</td>
<td>Aggressive spruce</td>
</tr>
<tr>
<td>Plant spruce only</td>
<td>380-434</td>
<td>42-48</td>
<td>18-20</td>
<td>292-325</td>
<td>Plant spruce only</td>
</tr>
<tr>
<td>Average spruce</td>
<td>424</td>
<td>47</td>
<td>18-24</td>
<td>288-385</td>
<td>High yield spruce</td>
</tr>
</tbody>
</table>

* Calculated as follows: 288/9 = 32; 385/9 = 43

### TABLE 6. Current forest product values in British Columbia

<table>
<thead>
<tr>
<th>Species</th>
<th>Stumpage ($/m³)</th>
<th>Purchased Log Price ($/m³)</th>
<th>Net Product Value ($/M³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>$0.25-0.50</td>
<td>$20-25</td>
<td>$0-75</td>
</tr>
<tr>
<td>Spruce</td>
<td>$6.7</td>
<td>$25.54</td>
<td>$0.130</td>
</tr>
<tr>
<td>Difference</td>
<td>12.28 fold</td>
<td>0.2 fold</td>
<td>0.2 fold</td>
</tr>
</tbody>
</table>

Sources: Bayard Palmer, Woodbridge Reed and Associates, Vancouver, personal communications Lousiana Pacific, Dawson Creek, personal communications Ainsworth Lumber, 100 Mile, personal communications
MANAGEMENT IMPLICATIONS
Silviculture Prescriptions

Aspen should be accepted as a crop species on medium sites in the boreal forest where vigorous, well-distributed suckering can be expected. Adequate density and growth rates can be achieved without reforestation treatments on many sites. Further research is needed to investigate the impacts of juvenile spacing.

Further research is also needed to identify appropriate treatments to encourage aspen suckering where poor distribution of mature aspen prior to harvest, or inhospitable environmental conditions create patchy distribution of regeneration. Once these treatments have been identified an analysis should be completed to compare these options with converting to pure spruce.

Where possible, understory spruce regeneration should be encouraged and managed. This option provides the greatest volume production at a relatively low cost.

Intensive, high yield silviculture should be practiced on sites where spruce plantations are established. Prompt control of competing vegetation and density management are necessary to realize maximum productivity from these sites.

Timber Supply

The northern timber supply areas are expected to experience conifer timber shortages in 50 to 100 years (Darrell Robb, TSA Planning Coordinator, Prince George Forest Region, personal communication). Spruce stands created by artificial regeneration over the next 10 years would likely be merchantable by this time, but they would certainly not produce their maximum volume or economic potential. On the other hand, aspen stands would be mature and available for harvest. The longrun timber supply situation should be considered when decisions are made to regenerate species with widely differing rotation ages.

Given the uncertainty surrounding the future value of different wood products it is a wise strategy to include a diversity of species and thus potential products within a supply area. Accepting vigorous natural regeneration of aspen on sites where aspen productivity is acceptable while establishing spruce mixedwood plantations on the remaining sites will result in a diversified ‘portfolio’ of species and thus products to take advantage of opportunities in an uncertain future marketplace.

Non-Timber Resources and Environmental Impacts

Successful establishment of spruce plantations on medium sites in the boreal forest requires aggressive site preparation, planting and brushing treatments. Competing ‘non-crop’ vegetation such as reedgrass (*Calamagrostis canadensis*), aspen and a number of shrub species must be controlled to ensure the crop seedlings survive and grow. These species have significant values as forage for range and wildlife species and as cover and habitat for a diversity of small mammals. Establishing spruce plantations simply may not be an acceptable strategy where non-timber resource values are high.

The site preparation and brushing treatments required to establish spruce plantations often include significant alteration to the soil environment and the use of chemical herbicides. The environmental impacts of these treatments may not be acceptable if they are applied throughout the forest.

**CAUTIONS**

This analysis is relevant for medium sites in the boreal forest where natural aspen suckering will be vigorous and well distributed. It does not apply to poor or good sites where aspen productivity is significantly lower than spruce. Nor can these results be transported outside the boreal forest where the relative productivity of aspen and spruce are undoubtedly different, and where other species (such as lodgepole pine) should also be considered. Differences in treatment costs and probabilities of treatment outcomes will also influence the acceptability of aspen on other sites.

This analysis is also not a justification to ‘log it and leave it’ on all sites in the boreal forest. The challenge for silviculturists in this area is to recognize the site and stand

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**TABLE 7.** Fibre price in Sweden and Finland

<table>
<thead>
<tr>
<th>Country</th>
<th>Hardwood Fibre Price (US$/tonne)</th>
<th>Softwood Fibre Price (US$/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>$116</td>
<td>$122</td>
</tr>
<tr>
<td>Finland</td>
<td>$127</td>
<td>$132</td>
</tr>
</tbody>
</table>

conditions at the pre-harvest stage that will result in vigorous suckering of aspen after harvest. Spruce plantations should be established on sites where aspen suckering is unreliable. You’re not off the hook in terms of reforestation up here in the north because of this analysis; but your focus should shift to the difficult task of successfully establishing spruce plantations mixed with natural aspen only on those sites where natural aspen regeneration cannot be relied upon.

I’d like to close with a word of advice to the silviculturists in the audience, and to anyone else who was little access to information on developments in forest products processing technology: it’s changing fast, and you should find a way to keep up with it. If we don’t stay informed we will soon find ourselves fighting to grow a crop that no one will buy.

REFERENCES CITED


STRATEGIES FOR MIXEDWOOD MANAGEMENT: 
A COMPENDIUM

T. JOHN DREW
Regional Director General
Pacific & Yukon Forestry Centre
Victoria, B.C.

I would like to summarize the highpoints of today’s 
discussion, at least as I saw them. I’d like to reinforce the 
technical messages, and summarize and integrate these 
with what we know in general about the subject of mixed 
wood management. I’d like to place all this in a decision-
making context and then try to help you reach your own 
conclusions about the management options that are before 
us.

Jamie Benson focused on inventory and made the 
point that we had to have better inventory and a stronger 
mixedwood classification system if we were ever going to 
make some intelligent management decisions in this forest 
type. He held out hope that we could increase our knowledge 
with tools, such as remote sensing models and hardware, 
that are now available to us. Craig DeLong gave us an 
overview of the ecosystem dynamic of the mixedwood 
forest and put forward the view that we must understand 
this dynamic and use the diversity of this ecosystem as an 
ally for increasing productivity.

Stan Navratil talked about regeneration in the mixed-
wood forest and suggested that we have basically three 
options for using the full site potential of this type: we can 
either grow hardwoods, we can grow for mixedwoods, or 
we can grow conifers. To make sensible choices, we need 
to understand what the goals of management are. Whether 
we like it or not, the hardwood component of our mixed-
wood forest is increasing. Stan talked about nature needing 
to be ridden, not driven, and that we must align the 
objectives of management with the inherent capacity of 
site.

Tony Sauder talked about harvesting and commented 
that often a lot of white spruce understory is left after 
harvesting mature aspen and conifer. For residual regen-
eration to work, five caveats were suggested. It now seems 
important that:

1) Mechanical felling equipment be used;
2) Felling equipment be well matched to both the 
timber and the terrain;
3) Trail and landing layout be well planned;
4) Supervisors be on-site (and committed to achieving 
results);
5) Results be shared.

Jan Volney reminded us that there is a large quantity 
of pest-related information available on the mixedwood 
forest, and that many of the pest management tools have 
been or can be easily developed; that we need to know the 
goals of management to direct the tools available; that 
expert systems are developed and available to help; and 
that pest management of the regenerated forests may be a 
very smart thing to do. He talked about logical strategies 
for pest management.

Norbert DeByle talked about integrated use and 
provided some insights on the other non-timber demands 
of the forest such as livestock, aesthetics, and water yields. 
He suggested that, in the U.S., no single value dominates 
and controls ecosystem management. He suggested, 
probably somewhat facetiously, that one will get conifers 
in the mixedwood forest — one just has to protect them 
long enough.

Cindy Pearce shared some thoughts on economics 
and put forward a method of economic analysis that she 
hoped would appeal to the forestry practitioner. Cindy 
talked about uncertainties, both biological and financial, 
and developed more of an estate planning approach to the 
economics. Cindy suggested that the relevant decision-
making variable ought to be the cost of creating a cubic 
metre of mean annual increment. She decided not to go into 
the more traditional time and timber value arguments.

The Oxford system of decimal classification (Table 
1) suggests to me that our panel have virtually addressed 
the "A to Z" of forestry for the mixedwood forest. We have 
talked about seven of the ten basic factors that we need to
consider when talking about forestry. We did not talk about marketing, and we did not talk about products and utilization. There are some other social aspects that ultimately need to be considered.

Table 1  
Lead Headings Of The Oxford System Of Decimal Classification For Forestry

| 0. | Forests, forestry and utilization |
| 1. | Factors of the environment |
| 2. | Silviculture |
| 3. | Work, harvesting, logging, transport |
| 4. | Forest injuries & protection |
| 5. | Forest management, economics, administration & organization |
| 7. | Marketing |
| 8. | Forest products and utilization |
| 9. | Social economics of forestry |

We know a lot about mixedwoods

We do know a lot about forestry and forestry management in the mixedwood region. If I had any worry with what we know about this forest, it is that we have accumulated much fact and information, but this information has not matured into knowledge, wisdom, and, in turn, better forest management. We must communicate facts to let them grow and become information. You have to pool information with acquired truths and principles so these, in turn, can become knowledge. That knowledge with insight leads to wisdom and it is wisdom that we need to guide forest management decision (Table 2).

Table 2  
The Maturation of Understanding

- FACTS when communicated become information
- INFORMATION pooled with acquired truths & principles becomes knowledge
- KNOWLEDGE with insight leads to wisdom
- WISDOM is what we need for good forest management
- CHALLENGES both the user and supplier of information to link with truth & insights or at least ask these questions

The disciplined use of information is virtually important for forest management decision-making in the boreal mixedwood zone of Canada. The need for mature viewpoints challenges both the supplier and the user of information. It challenges the user to make sure that the right questions are being asked: “Is this fact and this information going to help me build the knowledge and the wisdom that I need to make the forestry decisions that are important?” It challenges the supplier to make sure that the information being provided has the capacity to grow into knowledge and wisdom and therefore be helpful. I am reminded of words from Thomas Elliott’s poem “The Rock”. Elliott laments “where is the knowledge we have lost in information, where is the wisdom we have lost in knowledge” and then concludes on a real downer, “all our knowledge brings us closer to our ignorance.” Let’s not fall into the rather arrogant trap of looking for technical solutions when we are looking for technical answers; the solutions occur on a more social plain.

The pearls of wisdom

Let me share with you what I see as some of our bright lights of wise forestry thinking. In the same way that man has stood erect, so has forestry thought evolved (Figure 1). In forestry we have had our exploitation phase. Some may say we are still in it. Gradually, the ethics of conservation and sustained yield are evolving, growing slowly over time into an ethic of intensive forest management. I suggest that it is as inappropriate to think we can now exploit our mixedwood forest, as in days of old, as is unlikely that man will ever drop back to all fours and sustain himself on a diet of bananas. I don’t think the exploitation option is one that is rational for us, now. Environmentalists, our public, our whole industry won’t allow that, so let’s not debate at length the extensive options.

Figure 1  
Man and Forestry

In a biological sense, we know an awful lot about how trees and stands grow. In Connor Boyd’s 1985 talk to the University of Alberta, he suggested that growth from
Connor Boyd has examined forest investment on site three Douglas-fir land in western Washington (Figure 3). When net present value and discounted dollars are applied to revenue and costs, for this particular example, we develop an appreciation of silviculture for a range of opportunities that include planting, planting and thinning, and planting, thinning and fertilizing. The best financial decision in this case is one that doubles growth. What a spectacular impact such an investment would have on forestry. Actual volumes are only limited to the amount of land you harvest and the amount of dollars you have to invest in silviculture. If we were to double our allowable cut in British Columbia, as in this example, we could take our annual harvest up to 150 million cubic meters, perhaps in a time frame as short as three or four decades. We don’t have a timber supply problem if we get active with the silviculture opportunities that are available to us. First, there is a need to better understand the logic for investing in silviculture.

The decision making context

Carefully devised investment plans are needed if we are to meet public and community expectations.

CONCLUSIONS

I have been a silviculturist long enough to know that there is not just one ideal answer. Some insights and applications are identified in Table 3. However, the knowledge base is rich, probably richer than we are wise enough to apply. For instance, if we analyze the economics of silvicultural investments in the mixedwood zone, and the results show negative present net values — then we had

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Figure 2
Options: The Silviculture Opportunities

From: Boyd (1985)

southern pines with management is some 5.7 times that of the wild forest yield without management (Figure 2). John Gordon and others suggest that if you do everything right, in a biological sense, there may be a 22-fold increase under growth chamber conditions. If you don’t believe that, you should see some of Nick Wheeler’s results with extended photo-period and the like. There is an awful lot of biological things you can do to increase growth and the results are truly impressive. My friend, Stig Hagener from the Swedish Cellulose Company, Sundsvall, Sweden, suggests that growth with intensive forest management in that country may be somewhere around six times that of wild forest growth, independently verifying Connor Boyd’s earlier referenced views.

That substantial increases in forest growth occur with management is well and truly embodied in our knowledge base; however, we are not wise enough, it seems, to use this information at this time.

Bottom-lining investments in silviculture

Cindy Pearce, earlier today, expounded on some of the methods for economic decision-making in forestry. Clearly, to make wise silvicultural decisions, we have to understand the revenue and cost side of silviculture. Just knowing the biology is not enough; it leads one down the road of practicing forestry because it’s good for the soul, but not necessarily good for society or good for the pocket. We are going to have to understand costs of production, on one hand, and likely revenue on the other.

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Figure 3
Costs and Revenues: The Financial Opportunities For Silviculture

From: Boyd (1985)
better look for the structural impediments that cause this to be so. I think we need technical answers but the answers are not technical. The knowledge base does need regional calibration and knowledge needs fine tuning. The technical things should be done with the big picture in mind, though, to facilitate the growth of knowledge and wisdom.

What are the silviculture financial or social expectations of this mixedwood forest? I must confess that I don’t know; I know what they are from my perspective but I don’t know what the community sense of purpose is. I suggest that we better find out and ask these communities what it is that they want before we get carried away with the technical discussion about what some of the technical opportunities are.

In conclusion, I would like to take some license from the inscription on Wende Wilkie’s headstone. I believe in the northern mixedwood for here “we are blessed with natural and varied abundance (and I think),... we have great dreams and the opportunity to make these dreams come true.” We are, however, only going to realize these potentials if we don’t get overawed with the impediments or ambiguous about the objectives. We must be willing to move ahead with some passion to make what are reasonable dreams for management of the mixedwood come true.

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### Table 3
A Summary of the Main Messages

<table>
<thead>
<tr>
<th></th>
<th>Insight</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Knowledge</strong></td>
<td>The knowledge base on how trees and stands grow is rich</td>
<td>We don’t have to &quot;re-invent the wheel&quot; in order to make good management decisions in the mixedwood</td>
</tr>
<tr>
<td><strong>Calibration</strong></td>
<td>We need technical answers but the answer is not technical</td>
<td>• The knowledge base does need regional calibration, methods need fine tuning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Technical things should be done with the &quot;Big Picture&quot; in mind to facilitate growth into knowledge and wisdom</td>
</tr>
<tr>
<td><strong>Social Expectations</strong></td>
<td>Mechanisms for strategic planning exist from which a common sense of purpose and objective can be derived</td>
<td>• Effective management of the mixedwood requires that a consensus of purpose be arrived at</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• What is the silviculture, financial, social expectation for this forest?</td>
</tr>
</tbody>
</table>
Good evening.

Again it is my pleasure to speak to you this evening after what I feel was a most productive day.

Session One on 'The Mixedwood Challenge' was very informative, as was Session Two, on "Mixedwood Management Decisions: Elements in the Equation".

This morning, in my brief opening remarks, I outlined an historical perspective of British Columbia's new interest in deciduous species, the surge in investments in plants to produce products from aspen, and our eventual entry into the field of mixedwood.

The information we have attained from your learned observations and extensive experiences in mixedwood harvesting will help us develop effective policies for the harvesting, renewal and management of mixedwood stands.

For instance, our policies must consider the fact that deciduous species, such as aspen, grow faster than our coniferous species. I understand that poplars can have a far shorter rotation — just about 30 years — than our conifers.

We need to do more research to ensure that correct species are planted on suitable growing sites. With the big difference in age class, we have problems.

Which method of harvesting and which type of species should be used in reforestation — deciduous, coniferous, or both — are only some of the basic questions we have to address. To answer them, we have to look at the sites, their biogeoclimatic zone, their economic value to the province, the demand for their products, the markets.

At present, our policy is to reforest coniferous stands with coniferous species and deciduous stands with either deciduous or coniferous species.

As you are aware, British Columbia's forest industry accounts for more than 45 per cent of the value of shipments from all manufacturing industries in the province. Approximately 75 per cent of our forest products are exported.

At the national level, the province accounts for approximately 40 per cent of some $20 billion of exports in the forestry sector.

In terms of the world market, our province has 32 per cent of softwood lumber market, more than 14 per cent of the pulp market and more than 10 per cent of the newsprint market.

However, because our export markets are highly cyclical and subject to increasing pressures for protectionism, we must seize every opportunity to stabilize and expand our industry by:

- diversifying export destinations;
- expanding specialty, secondary and tertiary milling of solid wood products;
- updating our inventory of fibre suitable for pulp and paper products; and,
- using the previously non-commercial species, such as aspen and alder.

The last is the reason why we must look at mixedwood.

I mentioned this morning the investments being made in our province in chemi-mechanical pulp mills, with aspen as a desirable raw material.

But we need to move further . . . to use all species in mixedwood stands for a variety of finished products.

Alberta now has a pulp mill that is using a combination of aspen and spruce as the raw material to produce a high-value product. Tackama Forest Products uses balsam poplar and spruce in plywood.

We also need to harvest older stands, which have problems of decay and stain, and develop uses which minimize waste, such as for use in waferboard plants and pulp mills.
In British Columbia we need to develop strategies with regard to mixedwood management, because mixedwood will have a significant impact upon our resource and our economy.

The mixedwood challenge is dynamic.

There is the challenge of genetic improvement — to increase the yield of our mixedwood stands.

There is the challenge to develop harvesting systems for mixedwood stands so that the understory species that are not being harvested are not damaged.

The white spruce understory in the aspen stands is difficult to regenerate.

Therefore the protection of the understory will reduce the need for artificial regeneration and long-term tending of coniferous plantations.

Without suitable methods of harvesting, there is the danger that the volume of white spruce will steadily decline.

There is also the challenge to initiate forestry research, now concentrated on coniferous species, into the deciduous species.

The British Columbia Forest Service has now changed direction — from research into how to eradicate deciduous species, into research into how to grow and reproduce aspen.

We also have the challenge to harmonize our forest management with programs of other ministries, such as the Ministry of Environment, for the integrated use of our mixedwood stands.

We also need to use mixedwood stands for range. The former practice of burning aspen to provide for range was wasteful of the resource.

As you are aware, the Forest Service has stewardship responsibilities for all 'provincial forests' — 80.76 million hectares of Crown provincial land, or 85 per cent of the province’s total area.

However, as only about one hectare in four of the province’s total area — or 22.6 million hectares — is available for timber harvesting, we must make best use of every available hectare.

And every year, roughly one per cent of this available productive forest land is harvested to provide an allowable annual cut is 72 million cubic metres.

Because we have just started to harvest the deciduous species, we have yet to include the allowable annual cut of these species in our provincial total.

A bigger portion of the provincial allowable annual cut is today being allocated to our newly expanded Small Business Forest Enterprise Program.

I would like to talk about this program now for a few minutes.

We have expanded our Small Business Forest Enterprise Program and we expect to sell about 10 million cubic metres of timber annually under the program in the next five years.

The program has three primary objectives:

First, entry. We are providing entrepreneurs the opportunity to establish a new business in our forest industry through competitive sales.

Second, diversification and competition. We are selling a substantial volume of timber to promote and encourage the production of specialty and higher-valued, solid-wood forest products. We are also selling as much timber as possible through open competition to allow the most efficient entrepreneurs to win timber sales.

Third, profit. We are managing this program on a business-like and profit basis. We will return a dividend to the public for the timber sold. A new section in our Forest Act now allows timber sales to encourage and promote further manufacturing of timber and forest products.

We can now award timber sales, with five-year terms — 10 years in some instances — to entrepreneurs who submit the best proposals involving secondary manufacturing.

One company in Lillooet has received a timber sale licence under the program and will now be expanding its dry-kiln capacity to produce specific metric-sized, pre-cut, component lumber for use in traditional and pre-fabricated housing industries in Japan.

It is also producing select stock for the joiner market in the United Kingdom.
Its expansion will include equipment for finger-jointing, laminating, edge-gluing and other manufacturing.

Another specialty wood-manufacturer, this one in Penticton, has got a timber sale licence and is producing a range of pine furniture, including wall units, bookcases, tables, chairs and beds.

All units are packaged flat in ready-to-assemble kits.

Our new forest policies call for the reduction of the allowable annual cut of major replaceable licences, such as forest licences, and the Crown-land portion of tree farm licences, by five percent. This volume is being reallocated to the Small Business Forest Enterprise Program so that it can be expanded.

The program will also receive additional volume when there are ownership changes in major licences. With our expansion of the Small Business Forest Enterprise Program, we would like to see small business ventures taking a serious look at using coniferous tree species and mixedwood for their products, particularly in this region of the province.

There are great opportunities here and we would like British Columbians to seize them. The Forest Service has a mandate, under the Forest Act, to "encourage a vigorous, efficient and world competitive timber processing industry in the province".

Our Industry Development and Marketing Branch analyzes opportunities for expanding our forest products industry.

Our goals are to:

- minimize trade barriers;
- provide liaison for investors;
- ensure industry proposals having greatest economic merit are selected; and,
- improve legislation to further our forest products industry's vitality.

We have tremendous opportunities to diversify our export destinations and expand speciality, secondary and tertiary milling of solid-wood products.

We are pursuing these opportunities.

We have sponsored seminars to identify the needs of the secondary manufacturing sector.

Through this approach we hope to encourage research, development and technology transfer initiatives for remanufacturing and secondary manufacturing.

We are linking our research and timber harvesting policies and programs more closely to industry development.

In closing, I would like to say that this mixedwood symposium could not have been sponsored at a more appropriate time. We are today well on our way in developing a more diversified, stable and productive forest industry. Mixedwood management and development are the next logical steps for us to take in our approach to reap the benefits of our great forest resource.

We have lots of work to do, particularly in the areas of research, development and technology transfer. At the same time we must maintain the productivity and future ecological use of our mixedwood forests.

With the better understanding and the strong friendships that are being established at this mixedwood symposium, I am confident that we will be able to better manage our mixedwood forests, increase our productivity level, enhance our environmental issues, and endeavour to plan for our future and that of our grandchildren.

Thank you for your valued contribution to this symposium and I hope the rest of your stay in Fort St. John will be pleasant and enjoyable.
INPUT-OUTPUT ANALYSIS OF
THE FOREST UTILIZATION AND REPRODUCTION
IN THE UNION of SOVIET SOCIALIST REPUBLICS
(ECONOMIC AND ECOLOGICAL ASPECTS)

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Rector, Educational Institute in Forestry
The State Forest Committee
Moscow, USSR

THE ROUNDWOOD RESOURCE

The volume of roundwood removal and its distribution by regions depend on the following factors:

1. Demand for timber products of final consumption realized by sale and housing construction. The existing solvent demand of population can increase the consumption of some kinds of timber products two or three times (furniture, paper products, books, residential houses, etc.);

2. Wood consumption structure, reflecting the distribution of logs among different fields of wood utilization;

3. Raw materials potential estimated by the harvestable timber volumes;

4. Transport accessibility of the forest resources defined by the available rail-network, rivers for floating logs and roads;

5. Investment policy of the State (the volume of capital investments and its distribution among forest industries and forestry);

6. Technical changes in wood-working industries that allow to utilize all forest species and wood waste;

7. Forms of production organization represented by different types of enterprises with different levels of concentration, integration, cooperation and specialization;

8. Economic relations forming interconnections of enterprises and their higher institutions, State budget, banks, consumers and suppliers.

Let us consider the development of forest industries in the regions rich in forests where forest resources are represented by mixed forest stands. The regions rich in forest cover the European North, the Urals, Western Siberia, Eastern Siberia and the Far East. In these regions, forest industries and forestry are managed by the Union Ministry of Forest Industries. These regions provide a logging volume of 220-230 million m³ (about 60% of the total roundwood harvest).

In the poorly forested regions, forest industries and forestry are managed by the Republic Ministries of Forestry.

Let us now consider the economic characteristics of the forest industry in the regions rich in forest using the Input-Output Analysis (Figure 1).

The roundwood harvested in the regions rich in forest is to meet mainly the all-Union demands for timber and to be distributed by the centralized bodies along the following lines of final consumption: (%)

- construction - 11,
- pulp and paper production - 15,
- mining industries - 3,
- package - 17,
- furniture - 8,
- machine-building and wood-working - 6,
- maintenance and repair - 4,
- telegraph-poles - 1,
- internal market - 4,
- export trade - 13,
- fuel - 18.

The logging volume of 230 million m³ included 192 million m³ of industrial roundwood, including, in its turn, 88 million m³ of sawlogs, 37 million m³ of pulpwood, 7.8 million m³ of pitprops, 6.7 million m³ of veneer logs.
<table>
<thead>
<tr>
<th>REGIONS</th>
<th>FORESTED AREA (million ha)</th>
<th>GROWING STOCK (million m³)</th>
<th>Exploitable Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Coniferous Species</td>
<td>Total</td>
</tr>
<tr>
<td>The European North and The Urals</td>
<td>106.8</td>
<td>82.4</td>
<td>13.0</td>
</tr>
<tr>
<td>Western Siberia</td>
<td>90.3</td>
<td>57.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Eastern Siberia</td>
<td>241.7</td>
<td>191.6</td>
<td>29.6</td>
</tr>
<tr>
<td>The Far East</td>
<td>270.3</td>
<td>195.5</td>
<td>22.0</td>
</tr>
<tr>
<td>Regions Rich in Forest (total)</td>
<td>709.1</td>
<td>526.8</td>
<td>75.6</td>
</tr>
<tr>
<td>The USSR (total)</td>
<td>810.9</td>
<td>560.0</td>
<td>85.9</td>
</tr>
</tbody>
</table>

**Figure 1.**

Production Resources And Output In Forest Industry
### TABLE 2. Allowable Cut And Its Use By The Regions Rich in Forest.

<table>
<thead>
<tr>
<th>Regions</th>
<th>Allowable Cut (mln. m$^3$)</th>
<th>The Allowable Cut Used (%)</th>
<th>Thinning (mln. m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Including</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conifers</td>
<td></td>
</tr>
<tr>
<td>The European North and The Urals</td>
<td>171.3</td>
<td>107.6</td>
<td>61.6</td>
</tr>
<tr>
<td>Western Siberia</td>
<td>103.5</td>
<td>49.3</td>
<td>54.1</td>
</tr>
<tr>
<td>Eastern Siberia</td>
<td>174.2</td>
<td>125.6</td>
<td>48.6</td>
</tr>
<tr>
<td>The Far East</td>
<td>103.4</td>
<td>85.9</td>
<td>11.8</td>
</tr>
<tr>
<td>Regions Rich in Forest (total)</td>
<td>552.4</td>
<td>369.4</td>
<td>176.1</td>
</tr>
<tr>
<td>The USSR (total)</td>
<td>634.2</td>
<td>396.9</td>
<td>221.9</td>
</tr>
</tbody>
</table>

Forest enterprises produce also 12.0 million m$^3$ of wood chips from waste wood.

The roundwood is delivered to consumers by rail - 56%, by floating - 35%, by trucks - 9%. The mean distance of roundwood transportation amounts to 1800 km.

The raw materials potential of the regions rich in forest is shown in Table 1. This table indicates that 95% of the entire exploitable timber volume may be referred to the regions rich in forest (northern and eastern forests) but economically, their accessible resources amount only to 30-35 billion m$^3$ (60% of the exploitable volume).

The regions rich in forests are represented mainly by mixed stands where coniferous species are cut more intensively than deciduous species and larch due to lack of demand for these timber products and difficulties with the floating of deciduous trees and larch.

As a result, in many regions of northern and eastern forests, selective cuttings are carried out, i.e. only coniferous trees (pine, spruce, fir, cedar) are felled, and deciduous ones are left on the felling sites, considerably impairing the ecological conditions of the forest stands.

The allowable cut and its use are shown on Table 2.

It is necessary to pay attention to the problem of deciduous forest exploitation in the European part of the country where only 50-60% of the allowable cut for these forests is used. It considerably decreases not only the efficiency of logging but also the productivity of forest stands estimated by their current annual increment equal to 1.4-1.7 m$^3$/ha.

#### The Fixed Assets and Capital Investments in Forest Industry.

The technical development of the forest industry is determined by the value of fixed assets and annual capital investments. The estimated total value of fixed assets belonging to the Ministry of Forest Industries amounts to 24 billion roubles, out of which 7.45 billion roubles are slated for logging.

The unit capital investments in logging amount to 32 roubles/m$^3$. Besides, there are additional capital investments in the development of social infrastructure (housing, medical, trade services, etc.), which make up 20 roubles/m$^3$. 
There are significant differences in the unit capital investments by regions. To cut 1 m³ in Siberia, it is necessary to invest two or three times more than in the poorly forested regions.

The fixed assets in logging have lost their value by 40%, due to depreciation of machinery that makes the problem of the machinery renovation very serious.

The northern forests are exploited mainly through concentrated clear cuttings on the basis of tracked skidders and trucks.

The annual capital investments in logging amount to 400-500 million roubles, that is two or three times less than the normative ones. So the rate of capital renovation is rather low.

In the northern forests, the most widely used technology of logging is tree hauling to low landings where the trees are cross-cut, graded and piled before delivery to the consumers according to centralized distribution.

As for logging equipment, the following machines are used:

- trucks - 17,725 pcs.,
- railway rolling stocks- 2,425 pcs.,
- skidding tractors - 25,077 pcs.,
- felling machines - 2,100 pcs.,
- felling-skidding machines - 1,400 pcs.,
- limbing devices - 5,700 pcs.,
- timber loaders on forest sites - 8,100 pcs.,
- cranes at lower landings - 4,700 pcs.,
- semiautomated lines for cross-cutting - 1,300 pcs.

The above mentioned system of machinery ensures a 40% level of labour mechanization; manual labour prevails on cutting sites and lower landings.

Capital investments in logging are financed at the expense of the depreciation charge (70%) and profit (30%). The depreciation rates are stable in time (years) and vary with the types of machinery used.

It should be mentioned that one of the difficult problems of logging is road construction in the areas of extensive marshes and peatlands (30%). In these areas, winter roads are used for hauling. In some areas, it is expected to haul at tree lengths to the consumer yards (sawmilling, pulp and paper enterprises).

**Labor Resources and Wages.**

The forest industries have been, in many cases, the first ones to develop the sparsely populated areas in the European North and Siberia. And in these areas, the problem of labour supply remains rather difficult and the level of labour fluctuation is the highest one compared to other industries.

The total staff of the forest industry enterprises is 1,583,000 persons, including 1,353,000 workers.

407,000 persons are engaged in logging operations (348,000 of them are workers). The annual labour productivity in logging amounts to 660 m³/man, estimated as a ratio of annual volume of roundwood removal to the number of workers engaged in logging.

The mean monthly wage in logging amounts to 295 roubles which surpasses wages in other branches of the national economy (217 roubles) by 36%.

The mean monthly wages include:

- tariff wage in accordance with the existing tariff system,
- bonus payments,
- extra payments connected with regional factors (for remote northern and eastern areas),
- payments for long time services,
- overtime payments,
- extra payments for work on holidays and for night-time work,
- payment for holidays and other leaves.

Under the Economic Reform, the methods of wage calculation have been changed. Now wages are determined as a part of the net income of an enterprise (difference between the volume of sale and material cost with depreciation).

Successful solution of the problem of labour supply for logging depends on the development of social infrastructure (housing, medical service, trade, etc.).

**Power Supply in Logging**

The electric energy consumption per one worker amounts to: (in th. kwhr)

- logging - 4.9,
- sawmilling - 12.7,
- chipboards - 62.8,
- fibre-boards - 67.0,
- plywood - 9.8,
- pulp and paper production - 101.9.
Theses values have increased on the whole by 48% for the last 10 years. The unit consumption of electrical energy in logging amounts to 4590 kwhr.

Current Cost in Logging.

There are as a matter of principal two different methods of logging cost classification:

a. working out cost estimates,
b. cost-price calculation.

The cost estimates include the following uniform economic elements:

- raw materials and direct materials,
- supplies (wire, oil, instruments),
- fuel and energy,
- direct and additional wages of the whole staff,
- charge for social insurance,
- stumpage price,
- depreciation charge,
- miscellaneous money expenses.

The distribution of expenses by the above mentioned elements is characterized as follows: (%)

- direct and additional wages - 48,
- depreciation - 20
- stumpage - 11,
- power cost - 12.

Costs of production for individual goods are determined by means of cost-price calculation. In this case, costs in logging industry are divided into the following cost items:

- direct and indirect wages of logging workers,
- charge for social insurance,
- equipment and roads maintenance cost,
- stumpage price,
- all-shop expenses,
- all-Factory expenses,
- commercial expenses,

The unit cost in logging (price-cost calculation) amounted to 17.9 roubles/m3 in 1988 and has doubled since 1968. The cost rise in logging has been caused by:

- wages growth,
- increase in sale prices for machinery,
- decline of forest stands (reduction of the tree volume, growing stock per ha, increase of the hauling distance, etc.).

At present, the rate of profitability of logging industry (i.e., a ratio of unit profit to cost) is low (3%). 20% of logging enterprises do not cover the current cost, their financial losses are subsidized by the State. The mean sale price of roundwood amounts to 18.50 roubles/m2. To eliminate State subsidies in logging in 1990, it is envisioned to raise the sale price of roundwood by 60% and increase stumpage prices by 80%.

The Northern Forests - Main Ecological Characteristics

From the ecological point of view, the northern forests may be described as follows:

1. Low productivity of the forest stands due to the short growing season, low temperatures, extensive marshes and peatlands, and permafrost.

2. The mature and over-aged forest stands in the taiga zone are two-storied. The lower storey consists of young coniferous trees able to ensure proper regeneration only if the system of cuttings is changed. A system of selective cuttings needs to be introduced to replace concentrated clear cuttings. In this situation, there is a conflict between economic and ecological demands.

3. There are difficulties in using artificial forest regeneration (planting and seeding) due to poor soils, especially in the permafrost areas.

4. Over-aged forests are very susceptible to fire because of the high proportion of dead or damaged trees.

The Northern Forests - Goal Programmes

The ecological characteristics of the northern forest resources outlined above should be considered in the programmes for intensification of silvicultural activities to raise the ecological importance of the northern forests. The goal programmes should be based on the following measures:

1. Improving the methods of forest resources mensuration. It is envisioned:
   - to enlarge the network of the forest management and mensuration organizations;
   - to introduce on a large scale landscape-ecological methods of forest resource mensuration;
   - to extensively employ remote sensing techniques (satellite photography) to make regional forest cover maps.
2. Improving the final cuttings systems. The switch from clear cuttings to selective cuttings would make it possible:

- to increase by 30% the output of roundwood per ha,
- to significantly extend the harvesting period and thus create conditions for the constant supply of wood by integrated complexes,
- to reduce the volume of forest planting by relying on proper natural regeneration,
- to prevent the replacement of desirable coniferous tree species by undesirable deciduous tree species,
- to extend the environmental protection functions which are partially lost due to clear cuttings. According to our calculations, the ecological benefits resulting from selective cuttings exceed the costs.

3. Expanding the forest regeneration activities. At present, the rates of forest regeneration are lagging behind when compared to the rates of cutting. Forest planting has covered only 15-20% of the area assigned for artificial regeneration. The difference between the area cut and the area planted, taking into account natural regeneration, amounts to 30-35%, being one of the causes of forest land loss. The increase in unproductive forest area means that the environmental conservation functions of the forest are lost or lowered. This situation is particularly dangerous in mountainous and permafrost areas where the menace of soil and peatland erosion is very grave.

4. Expanding thinning programmes. Today, the area under thinning regimes amounts to only 7% of demand and only 0.7% of the forested area. Due to labour shortages in the forest workforce and the complete lack of demand for small-sized timber, it is envisioned that chemical methods should be developed for thinning young stands. This will, however, require constant ecological supervision.

5. Improving forest protection against fire and insects. In the northern forests, very high financial and ecological losses are caused by forest fires. In some regions, 10% of the growing stock has been destroyed and the quality of the stands has been reduced by 20-30%. The existing measures of forest fire control are applied only to forest areas under exploitation. Reserve forests are not protected against fires and insects.
TRENDS IN THE ECONOMIC, SOCIAL AND POLICY BASES FOR MANAGING MIXEDWOOD IN FINLAND

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ABSTRACT

Since the beginning of the 1960's, forestry and the forest industries have occupied a key position in promoting economic growth in Finland. As a result, the forest industries have expanded rapidly, with a simultaneous increase in forest improvement and management inputs. Despite the present pulping capacity, which is over 3.5 times as large as in 1950, the allowable cut is still estimated to afford a 15 per cent expansion of pulp output. The interplay between forestry, the forest industries and the national economy as a whole, has brought about an economic expansion with a feedback effect on the entire society. It has initiated a structural change in the more affluent society, with a consequent change in nonindustrial private forest ownership towards non-farm woodlots and new social values. In order to counteract the declining supply of roundwood and decreasing investments in forest improvements and management, new forest policy means are required. Economic theory suggests several possible policy means, but few of these will gain political consensus.

ECONOMIC GROWTH, FORESTRY AND THE FOREST INDUSTRIES

Finland is a country where the development of society as a whole is closely related to the interplay among forestry, the forest industries and the entire national economy. The benefits of this interplay were recognized at the beginning of the 1960's when a more conscious planning of the national economy proved necessary. Various alternatives for boosting the growth of the gross national product were explored. Owing to the dominating role of forests as a natural resource, investments for the expansion of the forest industries and a comprehensive intensification of timber growing turned out to be the most promising policy means for national economic growth.

An outcome of this expansive policy was that the pulping capacity was trebled during 1950-1970, while the expansion of the other primary forest industries was less drastic. At the same time, the consumption of industrial roundwood doubled. From 1970 to 1980 the processing capacity was increased by 20 per cent. The increasing need for industrial wood was supplied by transferring wood from other end uses, mainly fuelwood, by improving recovery and by increasing imports of raw wood. Removals from Finland's forests as such did not, however, increase.

This expansion of the forest industries would not have been possible without intensive forest improvement programmes, assuming a usual sustained yield. The timber growing investments amounted to a total cost of US$ 250 million annually (in real terms) in the 1970's and have since remained at the same level. This development has been induced by increased governmental intervention in private forestry through a combination of forestry legislation, cost sharing programmes and extension services. Consequently, as compared with the utilization of natural forests, capital intensity in forest resource management has increased. Even if actual achievements in certain types of forest improvement fell short of the set goals, the forest improvement output justified a considerable increase in the allowable cut.

These past periods were characterized by the expansion of the production potential in both forestry and the forest industries. However, the full utilization of these production potentials was not realized. Since the mid-
1960's the actual removals have remained below the allowable cut, 10 - 15 per cent on average. This is caused by a host of feedback effects following an increased influence in urban society, which in turn had effects on timber sales and on investment behaviour of non-industrial private forest owners. Through increased costs and prices, these influences also extended to the demand for raw wood. It is understandable that less than full utilization of forest resources will result in losses in employment, in national product, in rural income and in export.

Apart from these trends, there is another main reason to reformulate our public forest policy on managing the forest resources. Today, we are again facing an expansion phase in the forest industries, planned on the basis of the prospects outlined in the Forest 2000 Programme. By the year 1995, the ongoing and planned expansions will further increase, e.g. the pulp output by about 15 per cent. The actual removals should increase at least 10, perhaps 17 million m³. A vital question in forest policy is whether the forest owners are willing to increase their timber sales enough to shift the timber supply permanently to a level which supplies the additional raw wood requirement. Without policy intervention, many social and economic trends may endanger the achievement of the set goals for forest resource management.

CHANGES IN PRIVATE FOREST OWNERSHIP

The success of the forest policy is to a great extent dependent on the prevailing conditions in forest ownership and the changes in them. The following figures give a picture of the drastic structural change in private forest ownership and the predicted future outlook.

As compared with the traditional and rather stable forest ownership which was the majority of farmers, the new ownership group, i.e. non-farmers having an occupation other than farming, is very heterogeneous in their social economic status and living conditions. Moreover, the proportion of non-farmers is increasing rapidly and will soon become the majority.

The change in the main occupation of forest owners is only one feature revealing the ongoing structural change and social differentiation in private forestry, which will have effects on forest policy. The variation in the socio-economic background of forest owners has increased and resulted in diversified social values and goal setting in forest resource management. Most often, the changed forest management practice preferences are first encountered by the forestry professionals working in the field.

A trend that causes concern is the rapidly increasing number of those, most often absentee urban owners, who prefer other forestry benefits for efficient timber growing, such as recreation, amenity values and other intangible commodities. In the early 70's, 5 per cent and, in 1984, some 20 per cent of owners were in favour of the “green and soft values”, while, in the year 2000 their proportion is predicted to amount to 40 per cent. In addition, practical administrative difficulties in communicating effectively with the forest owners are caused by the fact that one third of them live permanently outside the woodlot and, by the year 2000, 60 per cent are likely to be absentee owners. It is understandable that all the forestry organizations, local forest management associations, forestry boards and timber purchasing firms, face a new and challenging situation to adapt themselves to the new ownership structure with new values.

Thus, there does not exist a “typical and representative” forest owner any more who could be described by average statistics. Studies on forest owners have shown to be different in background and management behaviour. For example, studies on timber selling behaviour indicate that there is a group of forest owners who do not fell many trees, whereas there are also those whose cutting intensity is twenty times as much.

The present situation reveals two main possibilities for forest economic research and policy development: in spite of the intensified timber supply research the supply forecasts will become increasingly uncertain; the general, non-targeted policy measures may lose their effectiveness and, therefore, we are in need of more differentiated means to address different forest owner groups.

<table>
<thead>
<tr>
<th>Table 1: Ownership structure in private forestry</th>
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<tbody>
<tr>
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<tr>
<td></td>
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<tr>
<td>1971</td>
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<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>% of the number of owners</td>
</tr>
<tr>
<td>Farmers</td>
</tr>
<tr>
<td>Non-farmers</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
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<tr>
<td></td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>% of the forest area</td>
</tr>
<tr>
<td>Farmers</td>
</tr>
<tr>
<td>Non-farmers</td>
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<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td>100</td>
</tr>
</tbody>
</table>
ECONOMIC TRENDS IN PRIVATE FORESTRY

Social conditions and economic basis are the other cornerstone in managing forest resources. The utilization of forest resources and investments in timber growing in private forestry are decisively dependent on the development of timber prices, stumpage earnings, costs of logging and silviculture and, hence, profitability. The main trends in economic development during the past decades have been favourable in that respect. To a certain extent, the economic situation has, however, changed in the late 1970's and during the 1980's.

Until the 1970's the increased demand for roundwood, together with rapid improvement in productivity (operational efficiency) in logging and especially in forest haulage have enabled an increase in stumpage prices. In real terms, the long-term average increase has been 1.5 per cent per annum. In the second half of the 1970's the growth levelled off and the real price level has been slightly declining since. This development is not due to unsatisfactory progress of productivity in logging and haulage; on the contrary, the operational efficiency in haulage trebled during the past ten years, while it improved by 50 per cent in logging. The costs of logging have remained at the same average level through the 1980's. The timber prices have followed the trends in export prices of forest products, there being a price agreement system between the interest organizations of the forest industries and forest owners. The world market prices have only recently allowed higher stumpage prices.

Likewise, the gross stumpage earnings of private owners have followed an increasing trend until the late 1970's, when the growth discontinued. During this decade stumpage earnings have, in real terms, amounted to US$ 25 billion on average.

The costs of silviculture show an upward trend. The real costs of artificial regeneration (planting) especially have risen rapidly, while the upward cost trend in other silvicultural activities like seeding and stand improvement has been less pronounced. Higher regeneration costs have, however, been partly compensated for by tax relief granted to properly managed regeneration areas.

As a result of the above trends, the business economic profitability of private forest management has slightly decreased. Moreover, the ongoing general tax reform in Finland is likely to add to the pressure of increasing the tax revenues from private forestry and, thus, further impair the financial yield to forest owners. Furthermore, due to moderate inflation and the developments in money and capital markets, the opportunity cost of timber growing has increased and, thus, forestry is likely to lose its earlier attraction as an investment alternative. The unifying Europe will put further pressures on forestry in terms of profitability and competitiveness.

A reason for both optimism and concern is brought about by the expected expansion of the wood processing capacity of the forest industries. As such, it will increase demand for raw wood from private forest and, hence, contribute to profitable forest management. On the other hand, if profitable timber growing as compared with other alternatives in the economy is not guaranteed in the long term, the domestic wood availability may endanger the expansion of the forest industry firms.

There are two main avenues to raise the profitability; in the short term, one can affect the timber supply to increase the cuttings to the level which the forecast at present allow; and, in the long term, to raise the operational efficiency both in logging and haulage, and especially in silviculture. It means increased mechanization, substitution of capital for the increasingly expensive labour. This is also the prospect in Finland in the 1990's.

However, there are obvious trends threatening this desirable development: increased fragmentation of private woodlots which reduces the economies of scale in forest management and adds to "the soft and green values" among forest owners and the general public. In addition, we are likely to face a rising cost level because the additional removals should increasingly result from thinnings.

In silviculture, we are left with an alternative which deserves serious consideration: to favour natural regeneration where possible more than at present, where it is biologically feasible. In practice, we can then favour mixedwood management by combining artificial and natural regeneration.

NEED FOR A REFORMULATION OF PUBLIC POLICIES

The rather small Finnish open economy, which is dependent on international trade and exchange, is sensitive to fluctuations in the international economy. In order to maintain both the external and internal balance of her economy, Finland has to employ active measures of public economic policy. Given the dominating role of forestry and the forest industries in the national economy, the general economic policy affects the production in forestry and the wood economy. In the present situation with the
expected expansion of production capacity in the forest industries in Finland, the balanced growth would presuppose that the general economic policy and public forest policy could find a parallel course. A high inflation rate with a simultaneous increased wood demand might induce an imbalance in the timber market.

The success in enhancing the growing stock and the allowable cut can partly be ascribed to the forest policy measures designed to stimulate the timber growing investments during the past decades. Through a combination of forestry legislation (Private Forestry Law, Forest Improvement Law, Law on Forest Administration, Law on Forestry Boards), state subsidies (grants and loans, tax exemptions) and overall promotion of private forestry (technical assistance, extension services for and education of forest owners) the private forest owners have been induced to invest in silviculture and forest improvement.

As described above, the production possibilities have not been fully utilized. Thus, the forest policy issues focus has clearly shifted from investment stimulation to the timber markets. If the planned investments in the wood processing capacity, in accordance with the removal targets expressed in the Forest 2000 Programme, are to be realized, the key issue in forest policy in the 1990's will be the timber supply from non-industrial private forests. This has also been recognized by intensifying research into the timber supply and the effectiveness of forest policy means.

What would then be the remedies to be recommended to shift the supply to the level the forest industries would require if the social and economic trends suggest a less desirable future? Economic theory might suggest a variety of possible means, but only a few may gain political consensus and be feasible. The Forest 2000 Programme provides three main policy domains to affect the timber supply: timber trade policy, general economic (fiscal and monetary) policy, and the forest policy proper.

A basic starting point in designing a forest policy programme promoting the timber supply is to explore to what extent the market forces, i.e. increased demand and, thus, a higher timber price, will affect the timber supply of private forest owners. Econometric research into the supply behaviour has given evidence of a rather inelastic timber supply, at least in the long term. In the short term, the price expectations caused by the price fluctuations, will counteract the positive stimulus of increased stumpage prices, resulting in smaller quantities of timber exchanged in the market than expected. This has also been recognized in the timber trade policy by attempting a smooth and moderate price development. In general, timber trade policy including agreements on recommended prices has been considered to have a positive influence on timber markets. The price ratio between sawlog and pulpwood is a means in guiding the composition of cuttings. The price differences have in that respect somewhat narrowed down recently.

The cuttings from private forests have their economic motives in the investment and consumption behaviour of forest owners. Thus, measures taken in money and credit markets or in fiscal policy will also have an effect on timber supply. The experience in Finland has indicated that a high inflation rate with a low real interest is a disincentive to cuttings; and, conversely, we may contribute to timber supply by low inflation and rather tight credit and interest rate policy. The substitution of borrowing for stumpage income as a means of financing then declines.

There are two main aspects associated with forest taxation: fiscal and forest policy. In Finland we employ an area-based yield taxation system in forestry which enables certain tax exemptions and reliefs on certain timber growing investments. The tax levied is independent of actual stumpage revenues. During the past ten years, the assessed taxable revenue has been, on average, 75 percent of the gross stumpage earnings. As such, the taxation system has been considered quite neutral as regards its impact on timber supply. In the long run, it has had an obvious positive influence on timber growing.

Recently, two issues on forest taxation have been discussed. First, the general tax reform is likely to expand the tax base also within forestry and, thus, to increase the taxable revenue. This fiscal aspect, however, has a counterpart in forest policy: What effects has the increased tax burden, for example on timber growing investments? Second, discussion has been initiated on whether the shift to the taxation of actual stumpage revenue would be a better alternative for forest owners. It is obvious that in the present situation it might lead to a decreased timber supply and, thus, endanger the planned expansion of the forest industries.

However, from the forest policy point of view a more defensible course has now been adopted: the government's proposal for the budget for 1990 contains a proposal on tax relief on first thinnings. Moreover, tax incentives for forest regeneration have been suggested to be tied more closely than before with the cutting decision taken by the forest owner. In short, the tax burden will shift slightly to old and mature stands, which is likely to give motivation to carry out final cuttings. All these means are in line with the tendency to shift the emphasis of forest policy in order to increase cuttings.
Among the forest policy means proper, the Forest 2000 Programme gives considerable weight to the intensification of forest management planning, combined with personal consultation with forest owners. To increase the effectiveness of management planning, development work is in preparation to improve the plans in order to achieve better than before the economic aims which forest owners set on their forest management. More generally, all the forest promotion measures, such as planning, training and services, are to be differentiated to meet the diversified needs and goals of different ownership categories. Both the channels used in communication and the technical contents of consultation have to be tailored to fit each forest owner segment.

REFERENCES


FINLAND: FOREST MANAGEMENT
IN A CHANGING ENVIRONMENT

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ABSTRACT

Finland's forest resources have increased down the years. Since a substantial amount of the cutting potential has been left unutilized and the availability of raw material for the expanding wood-based industry may become a problem, the whole forestry programme was recently updated. Among various measures for its implementation, an important role is expected to be played by management plans in small-sized private ownership. As regards deciduous trees, the consumption of birch wood by the Finnish pulp and paper industries has increased in recent decades. This makes conditions favourable for growing deciduous trees, not to mention the variety they add to the landscape, their ecological effects and the yield. Silvicultural systems need be developed further to utilize deciduous tree growing in either pure or mixed stands.

DATA ON FINNISH FORESTS
AND FORESTRY

Here, to start with, are a few figures with a bearing on Finnish forestry. Finland's population (5 million) amounts to 0.1% of the world total. Its share of other world totals is as follows (Key 1988):

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forests</td>
<td>0.5%</td>
</tr>
<tr>
<td>Coniferous forests</td>
<td>1.0%</td>
</tr>
<tr>
<td>Drain</td>
<td>1.5%</td>
</tr>
<tr>
<td>Fellings of industrial roundwood</td>
<td>2.5%</td>
</tr>
<tr>
<td>Production of forest industries</td>
<td>5.0%</td>
</tr>
<tr>
<td>Exports of forest industry products</td>
<td>10-15%</td>
</tr>
<tr>
<td>Exports of printing and writing paper</td>
<td>25%</td>
</tr>
</tbody>
</table>

Finland's forestry and wood-based industries directly employ 80,000 to 100,000 people, i.e. almost a fifth of the Finnish labour force. If the indirect effects on employment are counted as well as the direct effect, forest industries provide employment for more than 200,000 Finns in towns and country alike.

Two-thirds of Finland's land area is covered by forests whose total area is 20 million hectares with growing stock of 1800 million m³. These forests are mainly in private, non-industrial ownership: 63% of them belong to holdings with an average size of only 30 hectares. The State owns 24%, companies 9% and local authorities and parishes 4% of the area.

The main tree species in Finland are Scots pine, *Pinus sylvestris* (45% of the volume), Norway spruce (*Picea abies*) (37%), and two species of birch (*Betula sp.*) (15%). The remaining 3% is divided between alder and aspen. I'll return to the question of species later in this paper.
Finland’s forest resources, like those of its neighbours Sweden and Norway, have increased down the years. This is clearly shown by the results of the national forest inventories made regularly since 1921. The 8th National Forest Inventory is now under way. Surveys of wood utilization, made in parallel with the inventories of growing stock, give a reliable picture of the forest balance. Special importance is attached to regular repetition of these investigations: they have made it possible to follow and even foresee the trends in Finnish forests, and thus guide development in the direction desired.

Figure 1. Forest improvement and artificial regeneration

The progress depicted above has been achieved through improvements in forest management. Selective cuttings to a diameter limit have largely been abandoned. Other important measures that have increased timber production have been forest drainage, artificial regeneration and fertilization (Figure 1; Yearbook...1987). The driving force behind these measures has been the development programmes drawn up in the 1960’s which were funded by the Forest Fund Programmes (MERA), and partly, too, by a loan from the World Bank. But forest owners themselves have always played the decisive role.

Peat bogs were already drained on a considerable scale in the ’20’s and ’30’s. The 300,000 hectares drained in 1969 represented the peak of drainage during the MERA period. The present total area of drained peatland is well over 5 million hectares. Some 100,000 ha of forest have been fertilized annually during the ’80’s. Artificial regeneration became an important method of reforestation in the ’50’s. During the past 40 years a total of 7 million ha of forest have been regenerated - more than a half by planting or seeding.

Figure 2. Forest balance

This increase was also made possible by the fact that at the same time there was a considerable decrease in the consumption of wood for fuel and in exports of roundwood, and an increase of wood imports. The overall trend in total amounts of wood harvested has been downwards. A growth in the actual cutting potential has thus been left unutilized at the same time as the wood-based industries have experienced difficulty in procuring sufficient raw material.

In Finland, even small disturbances in the development of forest industries can weaken the balance of payments. Stable progress in these industries is a precondition for steady development of the national economy as a whole.

Under these circumstances it was decided to perform a study embracing the whole of the forestry sector in Finland. In February 1983, the Economic Council set up a Forest 2000 Programme Subcommittee to draw up a long-term programme for forestry and the forest industries in Finland. In addition to a steering group and working committee, working groups comprising experts from four
different fields were named to plan forest management and silviculture, the multiple-use of forests, timber procurement, and development of the forest industries. All this has stimulated forestry research in Finland. The overall Programme also included a special programme for development of forestry research. The original Forest 2000 Programme was finalized early in 1985.

The programme has been well-received on the whole, and the Finnish government has paid due attention to it in preparing the national budgets. Its implementation is also being monitored continuously.

The timber production targets of the Programme envisage a 25% (12 million m³) increase of the annual cut over the 1980 level by the year 2000. This goal presupposes a more effective utilization of the cutting potential than during the ’70’s and ’80’s. By the end of the century the cutting area will have to be enlarged by almost a third. The greatest expansion, 70% will have to occur in the area thinned annually. This means that the proportion of natural regeneration will have to be increased considerably in reforestation, though artificial regeneration will continue to be important. There will be a slight shift in emphasis from planting to seeding. Pruning of standing trees will increase.

Major changes are planned in basic improvements. All the new drainage operations are due for completion in the ’90’s. In addition redrainage, which includes ditch cleaning and supplementary ditching, will grow three-fold by 2000. Forest fertilization will be doubled. If the Programme’s targets can be met as proposed, the volume and annual increment of the growing stock will increase still further.

In drawing up the Timber Production Programme, more attention has been paid to the multiple use of forests. Raising the production of timber depends to a great extent on integrating it with other forms of forest use. Forest berry and wild fungi picking supplement timber production, and the berry crop can be utilized more effectively. Neither do game management or reindeer husbandry conflict with timber production to any marked degree. The value of other forest products compared to that of timber averages 10% in the whole of Finland, and 25% in the northern province of Lapland.

The recreational use of forests is fairly easy to integrate with timber production. Forest land set aside for conservation and recreational purposes totals 1.7 million ha in Finland. This area is not likely to be increased very much by the year 2000. It is estimated that multiple use will reduce the annual cutting potential by 2.2 million m³, i.e. by 3-4%.

PROBLEMS IN IMPLEMENTING THE PROGRAMME

The good management and silviculture practised during past decades has substantially increased the cutting potential in Finnish forests. Thanks to this, and to the good market for forest products in recent years, Finland’s forest industries are rapidly expanding. Annual investments are expected to exceed US$ 2 billion for many years to come. The expansion will apply mainly to paper and paperboard. On the whole, the trend in the raw-wood demand corresponds fairly well to the cutting targets of the Forest 2000 Programme. There is only one major exception: it is likely that some 8 million m³ of saw-timber sized trees will have to be used for fibre production. For instance, 40% of spruce saw-logs should go to pulp mills.

With these favourable prospects in mind, one may wonder if there are still any obstacles to progress. One factor requiring attention is the availability of raw material.

As mentioned above, a substantial amount of the cutting potential has been left unutilized since 1970, and the new goals presuppose a more effective utilization of this potential. We therefore need to be aware of the main reasons for this reluctance to fell adequate quantities of timber from Finnish forests.

The first point to be borne in mind is the structure of forest holding ownership in Finland. Seeing that 80% or so of the volume of timber supplied to the wood-processing industry has to be obtained from private forests, which average 30 ha in size and number almost 300,000, the importance of this form of ownership is decisive. There are many reasons for the hesitation to cut timber in these woodlots. Major changes have occurred in forest ownership during recent decades. More than a third of forest owners nowadays live away from their holdings. Their income and wealth have increased, and their dependence on revenue from their forest holdings has decreased.

Furthermore, the size of the annual cut is at the discretion of the forest owner. The most important stipulation in the Forest Act is that “The forest shall not be devastated.”, and the act specifies that prudent regeneration and growing measures be employed to ensure this. But it does not prescribe cuttings of any particular volume.

Secondly, certain measures in forest management - particularly forest drainage and large-scale regeneration cuttings and site preparation - cause temporary changes in the landscape, so they have come in for considerable criticism and have discouraged some of the forest owners from cutting.
Another cause of uncertainty is the threat posed by air pollution, the effects of which are hard to evaluate. The impact of air pollutants on forest ecosystems has attracted much attention, especially in continental Europe, where damage has occurred particularly in mountain forests. Two-thirds of the pollution load in Finland originates from foreign sources. The current situation is being evaluated by a systematic and multidisciplinary survey based on the network of permanent sample plots used in the national forest inventory. Damage trends will be determined with repeated measurements. Other research is being conducted on the mechanisms of forest damage, and possibilities of preventing and alleviating such damage by silvicultural measures.

Air pollution damage in Finland so far appears to be mainly local, and acid deposition is not likely to affect cutting volumes and forest management to any marked degree in the near future.

It is quite obvious that countermeasures are needed to overcome these causes of uncertainty among forest owners that are reducing the quantities cut. In particular, the role of management plans is becoming important. The regularity and intensity of management and cuttings made in private forests have been found to depend largely on how well the forest owners know their forests.

An effective way to increase the owner’s knowledge of their forests, and thus make fuller use of the cutting potential, is to draw up forest management plans. This activity involves the various forms of consultation. Considerable efforts have been made in Finland since the early ’70’s to increase the use of management plans. A coverage of 90% is the target for the first half of the ’90’s. It should be noted, however, that even if there are not written plans, technical advice needs to be continuously available for all forest owners through their forest management associations.

THE ROLE OF MIXED WOOD

The theme of this symposium is Mixed Wood. I understand that, until recently, British Columbia’s commercial forests were limited to coniferous species, but that certain deciduous species have been found to have commercial value. “A management strategy must be developed to strike a proper balance between coniferous and deciduous resource, and this strategy must take into account economic as well as biological factors” (NILS 1989).

So it may be of interest to you to consider the role of deciduous trees in Finnish forestry, though your deciduous trees include various aspen (Populus) species, whereas Finnish commercial forests contain two species of birch (Betula).

In recent decades a clear change has occurred in the part played by deciduous trees in Finnish forestry. In the ’50’s and early ’60’s they were still a problem for Finnish silviculture, because there was only a minor market for small-sized birch as industrial wood. Now, in the ’80’s, the situation has changed completely: birch has become a highly sought-after species for industrial pulp wood. This change will be clear from the following percentages depicting the industrial consumption of domestic roundwood:

<table>
<thead>
<tr>
<th>Year</th>
<th>Pine (%)</th>
<th>Spruce (%)</th>
<th>Deciduous (%)</th>
<th>Total million m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>44</td>
<td>49</td>
<td>7</td>
<td>31.4</td>
</tr>
<tr>
<td>1985</td>
<td>44</td>
<td>40</td>
<td>16</td>
<td>41.5</td>
</tr>
</tbody>
</table>

Pulp wood accounts for most of the increase of deciduous tree cuts from 2.3 to 6.7 million m³. Furthermore, 42% of the total 5.5 million m³ imports of industrial roundwood in 1985 were deciduous species, almost all of them pulp wood. The consumption of deciduous wood by the Finnish pulp and paper industries has thus increased substantially. This makes conditions favourable for growing deciduous trees in Finland, not to mention the variety they add to the landscape. Birch does not grow in pure stands, but it is more often mixed in stands dominated by Scots pine or Norway spruce. At all events, mixed-wood management is a highly topical theme in Finland.

Studies on the ecological effects of deciduous trees indicate that decomposition of their litter improves soil properties. The high calcium content of birch leaves stimulates microbe activity and speeds up the circulation of nutrients in the soil (Mikola 1985). The highest pH in the upper layer of the soil has been noted in stands with a large proportion of birch (Troedsson 1985). In other studies, too, mixed stands are found to have been healthier than monocultures (e.g. Rennerfelt 1946), and the microclimate of a mixed stand is unfavourable to a certain genus of harmful insects (Ozols 1960).

Much research has been made in Northern Europe on yields from mixed birch and conifer stands. Earlier studies showed that a birch mixture improves the diameter and
height growth of conifers (Lappi-Seppälä 1930, Jonsson 1962). It has also been demonstrated that Norway spruce stands with a birch shelter produce more wood than pure spruce stands do (Tham 1988). Finnish investigations have indicated that birch usually increases the total yield of mixed birch and spruce stands in terms of dry weight (Mieliikainen 1985).

An economic analysis shows that under certain conditions mixed stands are economically superior to pure stands, the optimum birch percentage being 20-60% (Valsta 1988).

Basing on positive research findings and practical experience, silvicultural systems have been developed to utilize deciduous trees growing in either pure or mixed stands. Naturally, considerably more research is needed to improve mixed-wood management.

REFERENCES


NILS 1989, Forestry mission proposal.


CURRENT AND FUTURE TRENDS IN HARVESTING, UTILIZATION AND PROCESSING OF MIXEDWOOD IN FINLAND

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Finland is a typically open economy with increasing dependence on the international market. As late as the early 1960's, a good third of industrial production was exported; today the proportion is 55%. A quarter of a century ago imported goods accounted for a mere 18% of the final domestic demand for manufactured products; today the figure is about 50% (Figure 1).

FINLAND'S EXPORTS DIVERSIFIED

Total exports at fixed prices have increased by 5.4% per year since the early 1960's; thus the value of exports has quadrupled in 25 years. The proportion of Finland's total exports accounted for by the forest industry has, in that time, been reduced from 69% to 37%. However, by the mid-1980's, the real value of forest industry exports had doubled the level of the early 1960's.

The metal industry has been the most powerful growth factor in exports, for its share of total exports has gone up from 10% in 1960 to the current 38%. Diversification in the structure of industrial production is partly based on know-how in wood processing. In the course of the years, an extensive industrial sector manufacturing paper mills and machinery for forestry has emerged in Finland. The country's expertise in building icebreakers is largely the result of a need to secure year-round deliveries in the export industry.

FOREST INDUSTRY - EXPORT INDUSTRY

A good 80% of the paper and paperboard industry's production is exported. The proportion accounted for by board has been declining slightly, which is due to the growth in domestic processing; there is a tendency to export an increasing proportion of the production as converted products.

The proportion of exports accounted for by wood pulp has also been declining. In the 1960's, market pulp still accounted for 46% of sulphate pulp production, but in the 1980's the figure has come down to a good 30%. This means that both production and exports by the paper and paperboard industry using pulp as raw material have increased substantially. The principle behind this trend is clearly a desire towards more value-added production.

Birch-faced plywood and coniferous sawnwood are the major Finnish export articles in the mechanical forest industry. A good 85% of plywood production and close on 65% of coniferous sawnwood are exported. The contribution of particle board and fibreboard to exports is declining, since they are typical standard products not sufficiently competitive on the export market; consumption of these products is increasingly shifting towards the home market.

In the 1980's, 39% of particle board production and 48% of fibreboard production have been exported (Table 1).
TABLE 1. The share of exports in Finland’s forest industry production, 1960-1986. (*)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous sawnwood</td>
<td>64,1</td>
<td>65,0</td>
<td>64,3</td>
</tr>
<tr>
<td>Plywood</td>
<td>84,8</td>
<td>84,6</td>
<td>85,8</td>
</tr>
<tr>
<td>Particle board</td>
<td>38,0</td>
<td>43,5</td>
<td>38,5</td>
</tr>
<tr>
<td>Fibreboard</td>
<td>66,5</td>
<td>55,1</td>
<td>48,6</td>
</tr>
<tr>
<td>Wood pulp</td>
<td>38,8</td>
<td>24,6</td>
<td>21,4</td>
</tr>
<tr>
<td>• mechanical</td>
<td>9,2</td>
<td>1,4</td>
<td>0,9</td>
</tr>
<tr>
<td>• chemical</td>
<td>49,9</td>
<td>35,2</td>
<td>32,6</td>
</tr>
<tr>
<td>Paper</td>
<td>82,6</td>
<td>82,0</td>
<td>82,9</td>
</tr>
<tr>
<td>Paperboard</td>
<td>83,5</td>
<td>79,7</td>
<td>78,2</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1968-62).

FINLAND’S EXPORT MARKET IN EUROPE

Europe is the most important marketing area for Finland’s forest industry. The proportion of total exports accounted for by the EC (12) was some 60% in the mid-80s, and the proportion accounted for by the whole of Western Europe some 69%. The UK alone accounts for a fifth of Finland’s total forest industry exports.

The plywood market is clearly anchored in Western Europe. Exports by the sawmill industry are concentrated on the EC area in particular. The largest market area for converted paper and board products comprises the Comecon countries, the Soviet Union in particular. The export market for paper products is considerably more extensive than that for the other product lines (Table 2).

GROWTH MOST POWERFUL IN THE PULP AND PAPER INDUSTRY

Production by the mechanical forest industry has not grown significantly since the early 1960’s. The fibreboard industry expanded vigorously in the 1960’s, but production in that sector has declined by the 1980’s. The sawmill industry has increased its production only very slightly (Table 3).

Pulp industry production has steadily increased since the early 1960’s. Production of mechanical pulp has nearly tripled, whereas that of chemical pulp has doubled. Production of semichemical pulp began, in its current scale, in the 1960’s. The production of sulphite pulp has decreased dramatically, as the production of sulphate pulp has increased to a level three times higher than at the start of the 1960’s (Table 4).

The paperboard industry grew rapidly in the 1960’s and is continuing to expand its production in the 1980’s. The growth in paper production has also been very strong,
### TABLE 2. Finland's forest industry exports by region, 1985-1987.

<table>
<thead>
<tr>
<th>Region</th>
<th>Conif. sawnwood</th>
<th>Plywood</th>
<th>Wood pulp</th>
<th>Paper</th>
<th>Paper-board</th>
<th>Converted pap&amp;board products</th>
<th>Total forest industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>79.3</td>
<td>90.7</td>
<td>84.3</td>
<td>74.5</td>
<td>80.9</td>
<td>93.7</td>
<td>81.2</td>
</tr>
<tr>
<td>- EEC</td>
<td>73.2</td>
<td>60.7</td>
<td>65.6</td>
<td>61.4</td>
<td>65.3</td>
<td>38.2</td>
<td>60.2</td>
</tr>
<tr>
<td>- EFTA</td>
<td>5.0</td>
<td>25.6</td>
<td>5.9</td>
<td>5.3</td>
<td>5.9</td>
<td>16.2</td>
<td>8.3</td>
</tr>
<tr>
<td>- CMEA</td>
<td>0.7</td>
<td>4.2</td>
<td>11.8</td>
<td>7.7</td>
<td>9.4</td>
<td>39.2</td>
<td>12.5</td>
</tr>
<tr>
<td>Asia</td>
<td>5.2</td>
<td>3.1</td>
<td>9.8</td>
<td>8.5</td>
<td>11.2</td>
<td>2.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Africa</td>
<td>15.3</td>
<td>1.6</td>
<td>2.5</td>
<td>1.6</td>
<td>3.3</td>
<td>1.2</td>
<td>3.2</td>
</tr>
<tr>
<td>North America</td>
<td>0.0</td>
<td>4.5</td>
<td>1.1</td>
<td>10.3</td>
<td>1.4</td>
<td>1.8</td>
<td>5.7</td>
</tr>
<tr>
<td>Latin America</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>2.4</td>
<td>1.3</td>
<td>0.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Oceania</td>
<td>0.1</td>
<td>0.0</td>
<td>2.2</td>
<td>2.8</td>
<td>2.0</td>
<td>0.6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

### TABLE 3. Production by Finland's mechanical forest industry, 1960-86. (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Conif. sawnwood m³</th>
<th>Plywood m³</th>
<th>Particle board m³</th>
<th>Fibreboard t</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>6866</td>
<td>378</td>
<td>79</td>
<td>184</td>
</tr>
<tr>
<td>1970</td>
<td>7087</td>
<td>677</td>
<td>428</td>
<td>241</td>
</tr>
<tr>
<td>1980</td>
<td>8610</td>
<td>605</td>
<td>725</td>
<td>152</td>
</tr>
<tr>
<td>1986</td>
<td>7592</td>
<td>592</td>
<td>592</td>
<td>106</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth, %/yr</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>0.3</td>
<td>6.0</td>
<td>18.4</td>
<td>2.7</td>
</tr>
<tr>
<td>1970-80</td>
<td>2.0</td>
<td>-1.1</td>
<td>5.4</td>
<td>-4.5</td>
</tr>
<tr>
<td>1980-86</td>
<td>-2.1</td>
<td>-0.4</td>
<td>-3.3</td>
<td>-5.8</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).
### TABLE 4. Production by Finland's wood pulp industry, 1960-1986. (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Mechanical</th>
<th>Semi-chemical</th>
<th>Sulphite</th>
<th>Chemical sulphate</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000 t/yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>988</td>
<td>68</td>
<td>1221</td>
<td>1266</td>
<td>3543</td>
</tr>
<tr>
<td>1970</td>
<td>1701</td>
<td>319</td>
<td>1370</td>
<td>2672</td>
<td>6062</td>
</tr>
<tr>
<td>1980</td>
<td>2276</td>
<td>297</td>
<td>730</td>
<td>3585</td>
<td>6888</td>
</tr>
<tr>
<td>1986</td>
<td>3016</td>
<td>325</td>
<td>402</td>
<td>4517</td>
<td>8281</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth, %/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>5.6</td>
</tr>
<tr>
<td>1970-80</td>
<td>3.0</td>
</tr>
<tr>
<td>1980-86</td>
<td>4.8</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

### TABLE 5. Production by Finland's paper and paperboard industry, 1960-1986. (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Newsprint</th>
<th>Printing &amp; writing paper</th>
<th>Kraftpaper</th>
<th>Other paper</th>
<th>Total paper</th>
<th>Paperboard</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000 t/yr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>798</td>
<td>238</td>
<td>287</td>
<td>125</td>
<td>1449</td>
<td>579</td>
<td>2028</td>
</tr>
<tr>
<td>1970</td>
<td>1299</td>
<td>919</td>
<td>468</td>
<td>309</td>
<td>2995</td>
<td>1272</td>
<td>4267</td>
</tr>
<tr>
<td>1980</td>
<td>1502</td>
<td>1995</td>
<td>535</td>
<td>285</td>
<td>4317</td>
<td>1448</td>
<td>5765</td>
</tr>
<tr>
<td>1986</td>
<td>1715</td>
<td>3513</td>
<td>568</td>
<td>300</td>
<td>6054</td>
<td>1663</td>
<td>7796</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth, %/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>5.0</td>
</tr>
<tr>
<td>1970-80</td>
<td>1.5</td>
</tr>
<tr>
<td>1980-86</td>
<td>1.8</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).
particularly on the part of printing and writing paper. Growth in this product group has been over 10% annually (Table 5).

With reason, it can be said that Finland’s forest industry focuses on those products and product groups which are best suited to domestic raw materials and to the country’s technical and marketing know-how. This is evidenced by the following figures:

**Finland’s share of global**

- forest resources: 0.5%
- coniferous forest: 1.0%
- total removals: 1.5%
- removals of industrial roundwood: 2.5%
- forest industry production: 5.0%
- forest industry exports: 15.0%
- printing and writing paper exports: 25.0%

**INCREASE IN FOREST INDUSTRY’S MARKET SHARES**

The Finnish forest industry’s success in exporting can be measured by examining its share of the market. Since the mid-60s, Finland’s production of coniferous sawnwood has remained at about 10% of Europe’s coniferous sawnwood consumption. The recession following what has come to be known as the first oil crisis was clearly reflected in the sawmill industry’s loss of competitiveness in the mid-1970’s. 1980 was a record year for the sawmill industry, with production rising to over 10 million m³, and the share of the market going up to nearly 13%. The plywood industry lost ground in the 1970’s, but through specialization has managed to improve its share of the market to about 12% (Figure 2).

The share of European paper and paperboard consumption accounted for by Finnish paper and paperboard production has risen from its level of a good 10% in the mid-1960’s to its current level of nearly 15%. This increase has been a consequence of the favourable market trends for printing and writing paper; during the same period, the market share accounted for by these products has risen.
from 7% to nearly 20%. The trends for the market share of newsprint indicate a particularly large cyclical fluctuation of between 26 and 16% (Figure 3). It should be pointed out, however, that in the mid-1980's as much as 25% of Finland's entire paper production was exported to countries outside Europe.

**USE OF PULPWOOD INCREASED**

Owing to developments in production, growth has been greatest in the use of wood by the pulp industry. Since the early 1960's, the use of wood raw materials has increased by around 3% annually. The use of spruce as a raw material for pulp production has not increased; the decreased use of spruce in the production of sulphite pulp has been offset by the increased use of this type of wood in mechanical pulp production. Of the various types of wood used in pulp production, the largest increase has taken place in the use of birch. As a proportion of the round wood used, birch now amounts to nearly one third, up from the few per cent which it accounted for in the early 1960's.

Wood imports have become an essential source of raw material for the pulp industry. In the mid-1980's, imports accounted for as much as 17% of the wood used annually by the industry, the Soviet Union being the largest supplier.

The use of domestic wood residues, mainly chips and sawdust from the sawmill and plywood industry have increased significantly in the pulp industry, rising from less than 2 million cubic metres in the early 1960's to the current 6.5 million cubic metres (Table 6).

Although industry's use of wood has increased one and a half fold since the early 1960's, the total annual drain on Finland's forests has diminished somewhat. This has been a consequence mainly of the decrease in the use of fuel wood and in the level of wood exports, which has not been offset by the increased use of wood raw materials by the industry.

Since the possibilities for cutting at a sustained yield have improved in Finland as a result of good silviculture and forest management, the Finnish forestry has undergone a transition from the period of overcutting in the early 1960's to the current period of underexploitation of forest resources. In the mid-1980's, nearly one fifth of annual forest growth was being left unused (Table 7).
### TABLE 6. Wood raw material consumption by Finland’s wood pulp industry, 1960-1985. (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic roundwood</th>
<th>Domestic</th>
<th>Imported</th>
<th>Total wood residues</th>
<th>wood</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pine (m³/yr)</td>
<td>Spruce</td>
<td>Birch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>4,70</td>
<td>8,98</td>
<td>0.69</td>
<td>14,37</td>
<td>1,80</td>
</tr>
<tr>
<td>1970</td>
<td>6,43</td>
<td>10,59</td>
<td>3.57</td>
<td>20,60</td>
<td>3,80</td>
</tr>
<tr>
<td>1980</td>
<td>7,30</td>
<td>8,90</td>
<td>4.01</td>
<td>20,21</td>
<td>6,39</td>
</tr>
<tr>
<td>1985</td>
<td>8,05</td>
<td>8,55</td>
<td>4.80</td>
<td>21,39</td>
<td>6,55</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mill. m³/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,17</td>
</tr>
<tr>
<td>2,54</td>
</tr>
<tr>
<td>3,50</td>
</tr>
<tr>
<td>5,76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth, %/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>3.2</td>
</tr>
<tr>
<td>1970-80</td>
<td>1.3</td>
</tr>
<tr>
<td>1980-85</td>
<td>2.0</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).

### TABLE 7. Total drain, allowable drain and forest balance, 1960-1985. (*)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total drain</th>
<th>Allowable drain</th>
<th>Forest balance</th>
<th>Non-conif.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pine</td>
<td>Spruce</td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>57,9</td>
<td>52,9</td>
<td>-2.1</td>
<td>-2.3</td>
<td>0.4</td>
</tr>
<tr>
<td>1970</td>
<td>56,0</td>
<td>58,6</td>
<td>-0.1</td>
<td>3.9</td>
<td>-1.3</td>
</tr>
<tr>
<td>1980</td>
<td>53,7</td>
<td>61,5</td>
<td>-0.1</td>
<td>3.6</td>
<td>5.1</td>
</tr>
<tr>
<td>1985</td>
<td>52,1</td>
<td>65,9</td>
<td>2.4</td>
<td>5.3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mill. m³/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5.0</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>7.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>Growth, %/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>-0.3</td>
</tr>
<tr>
<td>1970-80</td>
<td>-0.4</td>
</tr>
<tr>
<td>1980-85</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

(*) Figures in all tables are based on five-year floating averages (1960:1958-62).
EXACTING LOGGING CONDITIONS

The predominance of small-scale private ownership strongly influences the way in which the Finnish forests are managed and utilized. The average woodland area of a private forest owner is 35 ha, and the average sale consists of only 340 m³ of timber. These facts constrain mechanization and increase logging costs.

In addition to the 40 million m³ of timber cut annually from the private forests, another 10 million m³ is harvested in large-scale operations from state- and company-owned forests. Therefore, machinery and methods have been developed for both types of operations.

Majority of forests lies below an altitude of 200 m. Logging never takes place in real mountain conditions. Therefore, cable logging systems are not used.

The terrain is characterized of small hills. The slopes, seldom steeper than 20-30%, are trafficable with forest tractors. However, the soil is often stony and covered with boulders, or in flat terrain soft and swampy. This sets high requirements for the machinery and operational planning in off-road haulage. In the winter time the peat-lands freeze and the snow cover levels the ground surface.

One of the most important factors affecting the productivity and cost of logging is the size of the trees. Due to the climate the trees are relatively small in Finland. The average stem volume of harvestable trees is about 0.2 m³ for Scots pine (Pinus sylvestris) and Norway spruce (Picea abies), and 0.1 m³ for birch (Betula pendula and B. pubescens).

REPEATED Thinnings - THE BASE IN LOGGING SCHEDULE

The principles of forest management and exploitation in Finland are aimed not only to increase the yield but also to improve the species composition and quality of the timber.

Finnish cutting systems are characterized by repeated selective thinnings from below. The present thinning practice was accepted in Finland several decades ago as soon as the development of the pulp industries guaranteed markets for small-sized timber. Nearly all stands in southern Finland are thinned selectively from below twice or three times during the rotation of 70-90 years. As a result of tree size, the cost of logging is highest in the early thinnings and lowest in the final cuttings:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Approximate age, years</th>
<th>Relative cost of logging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precommercial thinning</td>
<td>10-15</td>
<td>300</td>
</tr>
<tr>
<td>1st commercial thinning</td>
<td>25-35</td>
<td>200</td>
</tr>
<tr>
<td>2nd commercial thinning</td>
<td>40-50</td>
<td>150</td>
</tr>
<tr>
<td>3rd commercial thinning</td>
<td>55-65</td>
<td></td>
</tr>
<tr>
<td>Final cutting</td>
<td>70-90</td>
<td>100</td>
</tr>
</tbody>
</table>

The results of the repeated thinnings can be seen everywhere in Finland: a favourable development in the structure of the forests, decreased natural loss, decreased amount of decay-defected timber, decreased amount of logging residue, improved species composition, and increased average tree size.

Compared with clear-cuttings, in the thinnings productivity of work is lower and mechanization much more complicated.

Consequently, the logging costs are higher and the stumpage prices lower. For these reasons it is presently not possible to reach the thinning targets of the national management programs, like Forest 2000, in the full scale. Less than 30% of all timber is harvested from thinnings presently.

INFRASTRUCTURE FOR TIMBER HARVESTING

The forest industry companies purchase two thirds of their timber standing. One third of the total annual cut is delivered to the road side by self-employed forest owners.

No matter what sale type is used, the forest industry companies buy the raw material through their own woodland divisions. The companies are thus responsible for most of the logging operations.

A majority of Finland's 24 000 forest workers are employed by the companies on a permanent basis. In addition to logging, the same workers take part in silvicultural operations such as planting and tending. About 400 forest workers complete a two-year forest workers' vocational programme annually.

The workers are paid by piece rate. The average daily earning of a worker using his own power saw is roughly 300 FIM or US$ 70. In addition, the employer has to pay another 150 FIM per day for social security, vacations, insurance, travel expenses etc.

The forest tractors, multi-purpose machines and timber trucks are owned by private contractors. Most of them have
a permanent contract with a timber company guaranteeing a
certain minimum amount of work per year or a certain
minimum annual earning. There were more than 2000 for-
warders and 1000 multi-purpose machines in Finland at the
end of 1988. Almost 300 forest machine drivers complete a
two-year training program annually.

The state supports forest road construction in private
forests with low-interest loans and free planning. The annual
work result in the whole country exceeds 4000 km new
permanent forest roads. The program has been successful in
decreasing the average off-road haulage distance in southern
Finland to some 300-350 m.

The long-distance transport always starts with a truck,
generally equipped with full trailer, but it often continues
with railway or floating. In 1987 as much as 26% of the total
performance in the long-distance transport (timber volume
multiplied by transport distance) of round wood took place
by bundle floating. The corresponding figures were 59% for
truck transport and 15% for railway transport.

LOG-LENGTH METHOD IN
HARVESTING

The Finnish harvesting technology is a result of the
forest ownership, the technical logging conditions, the forest
management principles and the infrastructure described above.
Compared with countries such as Canada, the United States
and the Soviet Union, the economic and technical conditions
are different and the ecological and environmental require-
ments often stricter.

The mechanization on off-road transport was started
with farm tractors during the late 1950s. The first forest
tractors in North Europe were Canadian-made articulated
skidders. However, because the skidders and tree-length
method were not fully satisfactory in the prevailing condi-
tions, Sweden and Finland were forced to develop new
machines and methods better adapted to their own special
needs.

A new type of forest tractor, load-carrying forwarder,
was developed in Sweden and Finland in the 1960's. The
development of these machines was first characterized by the
need for higher productivity and reliability. During the late
1970's increasing emphasis was put on ergonomic require-
ments. In the 1980's ecological and environmental expec-
tations such as avoidance of soil compaction and rutting have
affected machine and method development considerably.

As a result of this development, the forwarders and the
log-length method gradually proved their superiority. The
tree-length method today represents less than 1% of the off-
road transport of timber.

A proven alternative for raising productivity and bio-
mass recovery in early thinnings is based on whole-tree
logging. The most laborious work phase of manual timber
preparation, delimbing, is then abandoned and the above-
ground biomass of small-sized trees is recovered almost
entirely. The chainsaw worker only falls the trees, cuts them
into 5-8 meter sections, and bunches the lightest sections to
ease the loading of a forwarder.

DEVELOPMENT OF PRODUCTIVITY

In Finland the hand saw and axe were replaced by chain
saw at the end of the 1950's and in the beginning of the 1960's.
The introduction of the motor-manual timber preparation
methods increased the productivity of work significantly.
The muscle and machine input in the woods was reduced
further by moving part of the traditional forest work, such as
measurement, debarking, delimbing, and bucking, to more
favourable conditions at the mill.

At the same time, animal power in off-road haulage was
replaced by farm tractors and forwarders. In the company
operations today the haulage is based on load-carrying
forwarders, and in the small-scale operations of self-active
farmers on conventional farm tractors.

PRODUCTION OF PULP AND PAPER
INCREASES

The future of the Finnish forest industry has been
The programme was supplemented by the final report of the
Forest 2000 follow-up Committee, which appeared in spring
1989. According to these studies, Finland’s forest resources
provide a solid basis for the development of the forest
industry. Estimations of future consumption trends for various
products also show that increasing amounts of sawnwood,
wood-based panels, paper and paperboard will be consumed
in Europe.

According to a study published by the FAO and ECE in
1986 on trends in the forestry sector, consumption of forest
industry products in Europe should increase by the year 2000
as follows:

<table>
<thead>
<tr>
<th>Product</th>
<th>Low Estimate</th>
<th>High Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>sawnwood</td>
<td>+0.5</td>
<td>+1.4</td>
</tr>
<tr>
<td>plywood</td>
<td>+1.0</td>
<td>+2.1</td>
</tr>
<tr>
<td>particle board</td>
<td>+2.1</td>
<td>+2.9</td>
</tr>
<tr>
<td>fibreboard</td>
<td>+0.6</td>
<td>+1.4</td>
</tr>
<tr>
<td>total paper and board</td>
<td>+1.6</td>
<td>+3.2</td>
</tr>
<tr>
<td>• newsprint</td>
<td>+1.5</td>
<td>+2.7</td>
</tr>
<tr>
<td>• printing and writing paper</td>
<td>+3.2</td>
<td>+4.7</td>
</tr>
<tr>
<td>• other paper/boards</td>
<td>+0.6</td>
<td>+2.4</td>
</tr>
</tbody>
</table>
The Forest 2000 Programme estimates that Finland’s mechanical forest industry will hardly grow at all in the next several years. The production capacity of the sawmill industry has actually decreased by several million cubic metres in the 1980’s. Similarly, the number of fibre board plants has dropped from the seven existing in the mid-1970’s to the current three.

The report predicts the pulp and paper industries to be the main growth areas. It is estimated that production of wood pulp will grow from the 8 million tonnes recorded in the mid-1980’s to a level of almost 12 million tonnes by 1995. The strongest growth, over 4%/yr, is expected in the production of mechanical pulp, with growth in the production of chemical pulp set at about 4%/yr.

Exports of chemical pulp are not expected to increase much above the current level. This means that the paper and board industry would have to increase its production by some 5%/yr. The most marked increase, around 7.5%/yr, is expected in the production of printing and writing papers (Table 8).

If production expands as predicted and consumption of paper and paperboard in Europe continues to grow as outlined above, then the proportion of European consumption accounted for by Finnish production would remain at approximately the current level. The proportion of the printing and writing paper market would grow by a few percentage points, but growth would be substantially slower than in past decades.

The expanding forest industry would also increase its yearly consumption of wood raw materials. According to the Forest 2000 Programme, by 1995 use of wood by the forest industry would be over 14 million m³ greater than it was in the mid-1980’s. The underexploitation of Finnish forests would, therefore, also be reduced considerably.

In the mid-1990’s, however, the annual total drain on forest resources would remain millions of cubic metres lower than the level of annual forest growth.

REFERENCES

1. The Central Association of Finnish Forest Industries. Statistical material for several years.