MANAGEMENT AND UTILIZATION OF NORTHERN MIXEDWOODS

Proceedings of a symposium
held April 11–14, 1988, in Edmonton, Alberta

J.K. Samoil, editor

INFORMATION REPORT NOR-X-296

NORTHERN FORESTRY CENTRE
CANADIAN FORESTRY SERVICE
1988

Sponsored by the Canadian Forestry Service
in cooperation with the provinces of
Alberta, Saskatchewan, and Manitoba
under the auspices of the
Canada–Alberta Forest Resource Development Agreement,
Canada–Saskatchewan Forest Resource Development Agreement, and
Canada–Manitoba Forest Renewal Agreement.

Catalogue No. Fo46-12/296E
ISBN 0-662-16400-8
ISSN 0704-7673

This publication is available at no charge from:
Northern Forestry Centre
Canadian Forestry Service
5320 – 122 Street
Edmonton, Alberta
T6H 3S5

A microfiche edition of this publication may be purchased from:
Micromedia Ltd. Place du Portage
165, Hôtel-de-Ville
Hull, Quebec
J8X 3X2

Printed in Canada

Samoil, J.K., editor. 1988. *Management and utilization of northern mixedwoods.* Proceedings of a symposium held April 11-14, 1988, in Edmonton, Alberta. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-296.

ABSTRACT

The Management and Utilization of Northern Mixedwoods Symposium was held on April 11–14, 1988, in Edmonton, Alberta. Twenty-six papers were presented on past management practices, present management and utilization of softwoods and hardwoods, and future challenges and opportunities.

RESUME

Le Symposium sur la gestion et l'utilisation des forêts mixtes boréales a eu lieu du 11 au 14 avril 1988 à Edmonton, en Alberta. Les vingt-six mémoires qui y ont été présentés portaient sur les questions suivantes: pratiques de gestion passées; gestion et utilisation courantes des bois mous et des bois durs; enjeux et voies d'avenir.

FOREWORD

The Management and Utilization of Northern Mixedwoods Symposium is the second major conference organized by the Canadian Forestry Service under the auspices of the federal–provincial forestry renewal and development agreements in Manitoba, Saskatchewan, and Alberta. The first conference, the Geographic Information Systems (GIS) Workshop, was held in Winnipeg in February 1987.

The Mixedwood Symposium coordinators wish to acknowledge the following individuals for their contributions to the success of the event: Dave Kiil, Regional Director General, Canadian Forestry Service, Northern Forestry Centre (NoFC), for his encouragement; the directorates of the three forestry agreements for their support and funding; NoFC staff members John Mrklas, Claire Abma, and Avery Ascher for their help organizing the symposium and Ron Gorman and Diane Szlabey for coordinating the post-symposium tours; the NoFC editorial staff for producing these proceedings; and all the excellent speakers, moderators, and exhibitors for their top-quality presentations and displays, without whom this symposium would not have been possible.

Steve Price
Bob Newstead

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NOTE

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INTRODUCTORY COMMENTS AND WELCOME

A.D. Kiil
Canadian Forestry Service
Edmonton, Alberta

Ladies and gentlemen, it is a pleasure for me to welcome you to this symposium. We have had a touch of spring in the air for several weeks already and I am sure that this gathering will get the sap flowing as we contemplate the challenges and opportunities of mixedwood management and utilization.

As the moderator has indicated, I am pinch-hitting for Jag Maini, Assistant Deputy Minister responsible for policy and planning in the Canadian Forestry Service. Owing to an 11th-hour requirement to appear before the Standing Committee on Forestry and the Environment, Dr. Maini is unable to be with us this morning. He apologizes to the organizers and participants for this change in his plans, particularly because he has had a lengthy interest in northern mixedwoods.

Last year the Northern Forestry Centre of the Canadian Forestry Service, in cooperation with the provincial forest services in the three prairie provinces, initiated a series of what we consider major symposia to address significant forest sector topics. The inaugural symposium, entitled *Geographic Information Systems*, was held in Winnipeg in February 1987 and dealt with GIS applications in forestry. One of the keynote speakers at that workshop dealt with the increasing speed of change in the workplace and in our personal lives. His comments were directed at the high-tech world of GIS, but I believe that our focus on mixedwoods during the next two days will also deal with innovation and change. In fact, the notion of change can be considered as the single unifying theme for this series of symposia.

The forest sector in Canada and especially in Alberta is changing, and changing rapidly. Buoyant markets, new investment in production plants and forest management, and diversification of wood supply, products, and markets reflect this rapid change. These events have brought about new requirements and mechanisms for collaboration (e.g., the Canadian Council of Forest Ministers (CCFM), the National Forest Sector Strategy for Canada, and advisory structures for determining research priorities) as well as economic development (e.g., federal-provincial forest resource development agreements and the Western Diversification Initiative).

You are all aware of the influx of about $1.5 billion in new investment in Alberta's forest sector over the past couple of years. Aside from providing a major push for economic development and diversification in the province, these funds will also have an impact on policy issues, forest management practices, and research needs.

These impacts are felt and dealt with according to the individual mandates and priorities of the affected agencies, but they are also a responsibility shared by all forest sector participants. National forestry forums, convened under the auspices of the Council of Forest Ministers, have been particularly beneficial in bringing all forest sector partners together to develop coordinated strategies. One recent example of such consensus-building was a national forum on *Innovation and Technology: Science in the Forestry Sector*, held in this room just two months ago. The 13 recommendations generated by about 100 senior decision-makers were accepted by the CCFM on the spot. Furthermore, the ministers established an implementation committee (chaired by Fred McDougall) to develop an action plan by September 1988. This level of collaboration, involving participation of federal and provincial governments, the forest industry, universities, consultants, and others, is noteworthy and strongly evident in the organization and program of the present symposium as well.

Much of the new investment referred to earlier is directed at the management and utilization of mixedwoods (i.e., trembling aspen and white spruce) and the availability of these species for a range of products such as pulp, dimension lumber, newsprint, fine papers, oriented strandboard, and specialty items. The need for improved inventory data, better information about decay-age relationships, establishment of criteria for determining management intensity in relation to hardwood and softwood components, and the need for accurate growth and allowable cut estimates are but a few examples of the challenges and opportunities that we need to focus on during this symposium as well as in the months and years ahead. I believe it is important that we consider all aspects of mixedwood management from regeneration to utilization, including applications of state-of-the-art technologies (such as GIS for site classification and computer-based projections of annual allowable cuts) and the potential for both primary and secondary products. The result—an improved information base—will enhance our ability to synthesize data in support of policy development.

The Canadian Forestry Service has done considerable research in the mixedwood belt since the 1950s, but this activity has been somewhat sporadic in the recent past. A projected major increase in the utilization of a mix of aspen and white spruce by new production plants indicates to me that we must be ready to assign a greater research priority to help resolve mixedwood management and utilization problems. A few years ago we made a strong start in this direction by initiating a major vegetation management project in the Grande Prairie area. Although this work focuses on a "conifer priority", it is an excellent example of a multidisciplinary approach involving researchers and practitioners.

Based on advice and direction provided by our advisory committees and clients, planning is under way to identify the questions relevant to the launching of a new multidisciplinary R & D project concerned with the management and utilization of the mixedwood forest. I am confident that the deliberations and recommendations of this symposium will prove especially valuable in helping to define project direction and structure. We welcome your comments and advice on this new initiative, both during the symposium and as an ongoing feedback mechanism.

It is worth noting that the federal-provincial forest resource development agreements in the prairie provinces have provided significant funding for new applied research and development to meet the needs of forest management and industrial innovation. Particularly noteworthy is the emphasis given to forest products and utilization R & D in the Canada–Alberta Forest Resource Development Agreement, which provides better opportunities to integrate forest management, utilization, product development, and marketing activities. Hopefully, future accords of this type will provide for continuation of R & D funding and direct involvement of governments, industry, and universities in sustaining the progress made to date. It is important that your political representatives are aware of your needs and expectations in this area.

I would like to conclude my brief introductory comments by reiterating the notion that this symposium provides us with an excellent opportunity to address and examine the emerging issues and opportunities surrounding the benefits to be derived from northern mixedwoods. In view of the current restructuring of the province's forest industry in terms of size and product mix, we are faced with a challenge to come up with the necessary information for policy development, on-site forest management and utilization, and well-founded R & D in support of these activities. I am confident that the deliberations today and tomorrow will help shape our approach to effective management and utilization of the mixedwood resource for the benefit of the forest sector in the prairie provinces and throughout Canada.

With your support and participation, this symposium promises to be very interesting and productive. I sincerely hope that it will live up to your expectations.

Keynote Address:

MANAGEMENT OF BOREAL MIXEDWOOD FORESTS

F.W. McDougall
Alberta Forestry, Lands and Wildlife
Edmonton, Alberta

Good morning, and welcome on behalf of the Alberta Department of Forestry, Lands and Wildlife to this conference. I am pleased to see the high level of attendance, which I think is indicative of both the subject and the interest in the subject that we are currently experiencing in this province and across the west.

I must compliment the conference organizers. There are basically three elements to a successful conference, and they are the place, the time, and the people.

With respect to first of all the place, I think our organizers made the right decision in choosing Edmonton for this subject. Unlike some years ago, when they had us travelling to the spruce capital of Canada to talk about aspen management in Prince George, good judgment in this case prevailed. I find that there really is no better place in Canada to talk about mixedwood management than right here, for a number of reasons.

We have in this province 100 000 square miles of boreal mixedwood forest. That boreal mixedwood forest is characterized by good clay soils and will probably be our most productive forest region once we get it under management. I guess God in His wisdom, when he decided to put Ottawa in the province of Ontario and the Freshwater Fish Marketing Corporation in Winnipeg and blessed British Columbia with the coastal Douglas-fir forest, did two things for Alberta. He gave us a bit of oil and gas, and He gave us the boreal mixedwood forest. So, I think we have been blessed. It is a blessing that will take some time for us to capitalize on and to realize that it is a very productive, very major part of the forestry scene in Alberta. It has not yet contributed to our forest industry proportionately to its potential.

The industry in Alberta has largely been focused on the boreal uplands and the boreal subalpine and the very successful operations of Weldwood–Champion–St. Regis–North Western at Hinton. Much of our forest industry has been predicated more on the conifers in the other forest regions.

The sawlog industry in northern Alberta has been operating in the boreal mixedwood forest, but it has been operating on the remnants of the coniferous component that fires have left us to work with. We really have not tapped the potential of the boreal mixedwood in this province, but it is major.

Timing is another element of a successful conference, and again I think the choice of time was very propitious, very well considered. We are now experiencing a major move into the boreal mixedwood forests, beginning with the interest shown by Procter and Gamble a few years ago in the development of aspen hardwood kraft pulp, which opened the door into certain markets. The Daishowa project has opened the door into the Pacific Rim and I hope will establish aspen as a competitor for eucalyptus in the world paper industry. It could lead to very major developments. The Millar Western project in Whitecourt is based on chemithermomechanical pulping and should open the door into certain markets, certain paper products for aspen in that area. Of course, the Alberta Newsprint project will use aspen in newsprint production, again opening more doors for the utilization of aspen. So the timing is right.

Some questions arise out of these developments, however, when we get to the third element of a successful conference, which is the people. From a forestry perspective, when I see people here such as Ken Armson, Bill Young, Murray Little, and Dave Rannard, I have to say that you certainly have the right people here. Some of the issues we are going to face in the mangement of the boreal mixedwood forest are going to require input from people who are not foresters, however, and there is a tendency in the forestry community in Canada for foresters to talk to foresters to talk to foresters.

Yet, a lot of the decisions with respect to the boreal mixedwood forests are not going to be made by foresters. There is an important requirement here to involve wildlife management in a major way and to involve other elements in the resource management spectrum.

When we look at managing the boreal mixedwood forest, one of the tricks is going to be to prevent it from becoming the boreal hardwood forest. We all know from past experience what an aggressive, fast-growing, and strong species the poplars, especially aspen can be. Most foresters who at one stage or another in their career have worked on aspen conversion projects (that is, trying to get rid of aspen and to get spruce to grow in a boreal mixedwood) will know just how tough a species it can be, which is great if you are managing for aspen.

But we are going to try to manage the boreal mixedwood, I believe, for a continued presence of spruce for a number of reasons. We do have a need to maintain a diversified forest industry in the north. The sawlog and sawmill industry traditionally is going to continue to require supplies of spruce and pine timber, and from a wildlife perspective the diversity is extremely important.

We hear a lot about monoculture, and there is a major public concern about monoculture. Much of the concern about herbicide use is really a concern of people who do not want to see foresters succeed in converting the entire forest land base into a giant spruce plantation, and they have a real concern that this is happening. Most of those people obviously have not visited reforested cutover lands with extensive natural monocultures of lodgepole pine following fire and aspen following fire.

Despite the best efforts of foresters, when we cut lodgepole pine monoculture we are getting mixedwood stands back, again a reflection of the aggressiveness of aspen. But the concern is there that we will be moving to monoculture management, and I think we have to convince people that forest management in Alberta is going to be much more than just taking a single preferred species and trying to replicate it in the greatest possible volume.

Diversity is important. In the boreal mixedwood we have an opportunity to manage for diversity, but it is going to be difficult to maintain and improve spruce. There are other reasons for keeping spruce in the mix, one of which is that the spruce, under proper management and free of competition, actually will outgrow aspen on many sites in the boreal mixedwood. Now, that is not often evident, because spruce is so slow to get established and has such a tough time struggling through the competition without the use of herbicides.

When you discuss the topic of mixedwood management in Alberta, and I guess across the West, one of the issues is going to be where and when do we get to use herbicides. The only way you are going to get the public on your side with this issue is to establish that it is not going to result in monoculture management and that wildlife concerns are factored in. A lot of the misinformation that the public has right now about the results and effects of herbicides needs to be corrected and put right. This will require a major public communications job, which to this point the forestry community (at least in this province) has done very, very poorly in communicating its objectives, methods, and results with respect to the use of herbicides.

There are some very major challenges, and some of these challenges this audience is not well equipped to meet. There needs to be a broader mix of people involved when we try to discuss and set objectives for forest management in the boreal mixedwood forest. We need a nonforestry component involved, and I would urge you in the future to try to make that change. It certainly is important in your discussions here that you keep in mind constantly the need for that additional input in those other considerations. Without public support for these objectives, forest management will continue to struggle with the political problems it is experiencing right now.

AN ECOLOGICAL PRIMER ON MAJOR BOREAL MIXEDWOOD SPECIES

E.B. Peterson
Western Ecological Services Ltd.
Victoria, British Columbia

Any one forest ecosystem in the northern mixedwood region is characterized by relatively low species diversity when compared with forested ecosystems in more southerly regions of North America. The overall diversity of forest vegetation is substantial, however, in a geographic area as large as that shown on the map logo for this symposium. The broad curved band of northern mixedwood forest that sweeps from Alaska down to Lake Superior and then across to Newfoundland contains a relatively large number of tree species and ecosystems in comparison to the more restricted Mixedwood Section (B.18a) as defined by Rowe (1972). The broad zone shown on the symposium's map logo is referred to here as the northern mixedwood region, without attempting to define the region ecologically.

At the outset I want to stress that the northern mixedwood region has a very impressive knowledge base already. Although several authors are cited in this summary, there are many more researchers and silviculturists, too numerous to acknowledge individually, who have developed an excellent information base on the ecology of the dominant tree species, especially white spruce (*Picea glauca* (Moench) Voss) and aspen (*Populus tremuloides* Michx.). The challenge of this symposium is to integrate information from those who are coniferous specialists with information from those who are northern hardwood specialists in order to arrive at new approaches to northern mixedwood management, a subject addressed by several other speakers at this symposium.

The northern mixedwood region is characterized by the presence of geographically wide-ranging tree species, as well as wide-ranging nontree species that are of silvicultural importance—species such as bluejoint (*Calamagrostis canadensis* (Michx.) Beauv.) and snowshoe hare (*Lepus americanus* Erxleben), to mention two examples. The silvicultural significance of these last two species is discussed later in this paper.

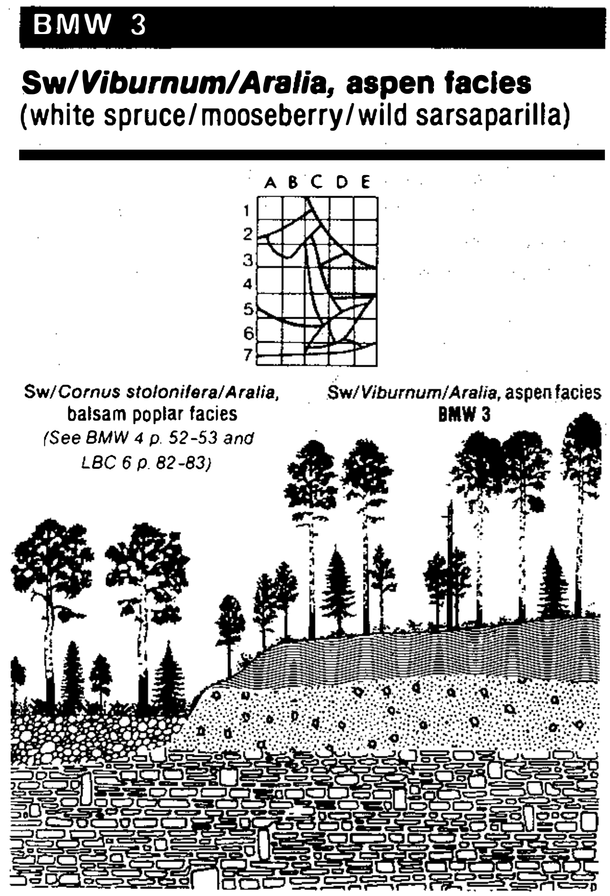
In a short review it is not possible to summarize the ecology of all of the tree species that occur in the northern mixedwood region. Therefore, I want to focus on the two dominant species, white spruce and aspen. To focus the subject even further, I will concentrate on the part of the range of these two broad-ranging species where they are at their best, and that is on mesic, nutritionally rich sites in the northern mixedwood region. By focusing on the portion of their geographic range where these two dominants coexist on mesic sites over large areas of land, it is possible to set aside the ecological restrictions that occur at the southern or northern limits of their geographic distribution. An example of the kind of ecological restriction referred to may be observed near the southern limit of aspen's distribution in the Park Range of Colorado, where aspen occurs only on south-facing slopes, with conifers restricted to north-facing slopes. In contrast, at the northern limit of white spruce distribution in the Richardson Mountains, Yukon, aspen is not present at all and white spruce occurs only on south-facing slopes, the same aspect that was dominated by aspen at the latitude of the Park Range in Colorado.

With such broad-ranging species, it is important to reiterate a point made by Larsen (1980) as a result of his examination of growth rates of black spruce (*Picea mariana* (Mill.) B.S.P.) from south of 50° latitude to north of 60° latitude. Near the southern part of the boreal forest and in the northern mixedwood region, black spruce occurs over a wide range of sites and displays a wide range of growth rates. In contrast, farther north the rate of growth on optimum sites does not greatly exceed the rate on the poorest sites. The mixedwood region that is the subject of this symposium is in the southern part of the latitudinal gradient of growth rates portrayed for black spruce by Larsen (1980). This suggests that site classification is particularly important in the northern mixedwood region because it is a zone in which there is a broad range of site and productivity alternatives for the dominant tree species that occur in the latitudinal mid-range of their large north-south geographic distribution.

On a national scale, the northern mixedwood region is not one of exceptionally high values for forest standing crop. A nation-wide map prepared by Bonnor (1985) reveals that stands with average coniferous biomass in excess of 100 t/ha (dry weight) occur predominantly in British Columbia, although there are significant occurrences of similarly high coniferous standing crop on the eastern slopes of the Rockies and across to the Swan Hills in Alberta. Bonnor's (1985) map of average biomass for northern deciduous species indicates that map units with an average standing crop greater than 100 t/ha occur predominantly in northeastern British Columbia, with minor occurrences in the Hudson Bay area, Saskatchewan, and a few locations in Ontario between Lake Nipigon and Lake Superior and northeast from Lake Superior towards Kirkland Lake. To put these standing crop estimates in perspective, Bonnor's (1985) estimate of the overall average standing crop for productive forest land in Canada is 89 t/ha, with British Columbia having the highest provincial average of 178 t/ha on productive forest land and the highest average for individual forest types at 1100 t/ha. Bonnor's mapping technique, which shows average standing crop in each of 50 000 cells across Canada, does not allow portrayal of higher-than-average standing crop that may exist on specific sites or in specific forest types. For example, Peterson et al. (1970) referred to an example of a 55 year-old aspen stand near Lesser Slave Lake, Alberta, where standing crop was 290 t/ha (dry weight).

For the purposes of this symposium, the focus is on the good to excellent sites that are characteristic of mixedwood stands. Pierpoint (1981) showed that the main occurrence of mixedwood stands in Ontario was on sites that had rich to very rich nutrient regimes and fresh to moist soil moisture levels. Although Kabzems et al. (1986) did not portray their information on a nutrient-moisture grid, their information from Saskatchewan also revealed that mixedwood stands occupied fresh to moist sites, and relatively nutrient-rich sites, comparable to those described by Pierpoint (1981) in Ontario. The nutrient-moisture grid for the white spruce/mooseberry (*Viburnum edule* (Michx.) Raf.)/wild sarsaparilla (*Aralia nudicaulis* L.), aspen facies ecosystem in the area studied by Corns and Annas (1986) reveals that the same is true in Alberta (Fig. 1).

Although the emphasis in this review is on sites with little or no nutrient and moisture limitation, it is important to realize that the northern mixedwood region does contain a broader range of ecosystems that silviculturists must deal with. These other forest ecosystems, not described in this review, include: forest types dominated by balsam fir (*Abies balsamea* (L.) Mill), a species that is increasingly important as one progresses eastward from Manitoba; forest types dominated by jack pine (*Pinus banksiana* Lamb.) on the drier parts of the toposequence; forest types dominated by black spruce or larch (*Larix laricina* (Du Roi) K. Koch) on the poorly drained parts of the toposequence; balsam poplar (*Populus balsamifera* L.) ecosystems; pure stands of white spruce on alluvial sites; forest types with abundant white birch (*Betula papyrifera* Marsh.); and ecosystems that contain a significant component of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), often mixed with one or both of aspen and white spruce. Mixedwood stands characterized by a significant lodgepole pine or jack pine component are left to later speakers or perhaps a separate symposium.



MANAGEMENT INTERPRETATIONS

Season of harvest	Logging method	Site preparation intensity	Soil compaction hazard	Soil puddling hazard	Soil water erosion hazard	Reforestation: Species selection	Reforestation: Method	Reforestation: Limitations	Reforestation: Frost heave hazard	Vegetational competition: Type	Vegetational competition: Severity	Windthrow hazard	Snowshoe hare damage hazard
W	CC	M	M-H	M-H	M-H	Sw	BR, C	excess moisture on some sites	M-H	aspen, *Calamagrostis*, forbs, shrubs	H	M	H

Figure 1. The main mixedwood ecosystem in west-central Alberta (the white spruce/mooseberry/wild sarsaparilla, aspen facies) and its location on the nutrient-moisture grid. (Source: Corns and Annas 1986).

The omission of balsam poplar from this overview may have been an oversight because this species is an integral part of many aspen stands, apparently more so in Alberta than farther east in Saskatchewan and Manitoba. In the more easterly locations, there is often a clear site distinction between balsam poplar stands and aspen stands. In Alberta, where upland aspen stands can contain a higher proportion of balsam poplar, the latter species is a management concern because it is less desirable than aspen for utilization (Denney 1987). The silviculture, management, and wildlife habitat role of northern hardwood stands that contain balsam poplar, as well as stands with residual standing balsam poplar after aspen removal, are subjects not yet well-documented.

The focus of this paper is the marked variation of stand conditions that can occur within the white spruce-aspen ecosystem. For example, the mixedwood monograph by Kabzems et al. (1986) includes a photograph of a stand that developed following a severe fire, in which spruce and aspen coexist in a comparable height class because both started to grow at the same time after the fire created a suitable regeneration medium. A companion photograph portrays a stand that developed after a light fire, where aspen established immediately and spruce regeneration came in slowly over a long period of time. Variations in ecosystem development may also be a result of influences other than fire. For example, Rowe (1955) described variations in successional trends in north-central Saskatchewan that are explained by land type rather than fire history. In that area, aspen stands that occur on low, narrow till ridges between intervening depressions of black spruce develop into a black spruce cover type. But on dry, sandy landforms in the same region, aspen stands may change gradually to self-perpetuating jack pine forest, or to white spruce–jack pine on south-facing slopes and to black spruce–birch on north-facing slopes. Such variability is one reason why site classification is so important to boreal and mixedwood silviculture, as described in more detail by Ian Corns in his paper presented to this symposium.

The proportions in which spruce and aspen intermix vary widely. Stands in the northern mixedwood region include: pure stands of spruce surrounded by essentially pure hardwood stands, generally a result of fire boundaries; pure stands of aspen; and aspen overstory with a variety of spruce age classes in the understory. The important point is that not all of the northern mixedwood region supports mixedwood stands; many of them are, in fact, pure stands of either northern hardwoods or conifers. In the portion of the northern mixedwood region where agricultural and forest land uses occur near each other, it is in the pure hardwood stands that the greatest land-use changes can be expected to occur in the future. Up to now, the most common form of "silviculture" has been to cut, pile, and burn aspen for conversion to agricultural land. That priority is apt to change dramatically as we now enter an era of aspen utilization in the northern mixedwood region, with increased interest in harvest of forest biomass from privately owned woodlots as well as from crown lands.

The clonal distribution of aspen is a subject so well documented in the literature that it needs no elaboration in this overview. The subject is mentioned here simply as a reminder that there is not yet a widespread understanding of the silvicultural consequences of managing stands in response to clonal regeneration behaviour. This circumstance exists despite the considerable literature on the subject (such as Steneker and Wall 1970; Steneker 1976; Heeney et al. 1980). At a recent symposium, Navratil (1987) suggested that the concept of silvicultural manipulation of clones to encourage those that possess superior qualities may have been oversold, mainly because several rotations would be required to bring about significant expansion of one aspen clone at the expense of another. Notwithstanding this caution, aspen silviculture is likely to continue to be, in the forseeable future, predominantly clonal silviculture. One reason for this prediction is the widespread occurrence of aspen stands that have regenerated from root suckers. Furthermore, even if aspen trees of seedling origin are more common in western Alberta than previously thought[1], there is reason to expect that each surviving seedling-origin stem will eventually develop into a clone of stems interconnected by a common root system.

As we move toward silviculture based on the clonal nature of aspen stands, it is important to note that aspen clones in the northern mixedwood region are generally very small, normally a fraction of one hectare. For example, to cite an extreme case, Steneker (1973) observed an estimated 1000 clones per hectare in a study site in Manitoba. At the other extreme, outside of the northern mixedwood region, individual clones of up to 40 ha have been recorded in the United States (Kemperman and Barnes 1976). Clone identification and management on an individual clone basis is likely to find its first silvicultural application in the context of decay management (Hiratsuka and Loman 1984). Recognition and encouragement of clones that have superior growth rates or preferred utilization characteristics, which may involve triploid clones (Einspahr et al. 1963), will come later.

There are major understory differences between spruce-dominated stands and aspen-dominated stands. The most conspicuous difference is the relatively poor

[1] Personal communication, 1988, from J. Fochler, Alberta Forest Service, Spruce Grove, Alberta.

development of herb and shrub cover, amid substantial development of moss cover, under spruce canopies. In contrast, no distinct moss layer occurs in aspen-dominated stands, but herb and shrub understorys are exceptionally well-developed. Many ecologists have attributed the relatively lush understory of aspen stands to the sparse crown development in the aspen canopy. The greater light penetration beneath an aspen canopy, in contrast to that beneath coniferous stands, may be the main reason for the well-developed herb and shrub layer beneath aspen canopies, but the well-developed understory may also be influenced by the fact that such ecosystems are relatively nutrient-rich, with the capability to support a significant shrub and herb biomass. One distinctive feature of the aspen understory, not widely reported in the literature, is the occasional presence of a juvenile understory of aspen beneath a mature or overmature aspen overstory. There is a tendency to think of aspen in terms of predominantly single-storied, even-aged stands but there are a number of circumstances where a two-aged aspen stand can develop. Such stands have been observed by the author in the Lesser Slave Lake area of Alberta. They are also described by DeByle and Winokur (1985) for the southern Rocky Mountain region.

I want to refer to the ecology of fire in the mixedwood forest only in relation to the concept of forest succession. This topic was reviewed by Rowe (1961) in an article entitled "Critique of some vegetational concepts as applied to forests of northwestern Alberta", a discussion that deserves rereading by any northern mixedwood silviculturist or ecologist who has not read it recently. It is instructive to repeat Rowe's perspective on fire in boreal and mixedwood ecosystems in relation to the traditional concept of succession. Traditionally, succession is viewed as a consistent, undirectional change of species composition over time. Most of the vegetation changes in fire-dependent forests, however, do not fit this concept. Most species of the northern mixedwood region become established in the first few years after fire and many individuals of many species are not eliminated from the site by fire. Even if aboveground parts are killed, vegetative reproduction and seed germination, either from organic layer seed banks or canopy-stored seeds, ensure a rapid new crop. Many stands regenerate to a composition almost identical to that of the burned stand. Although Rowe (1961) did not use these words, the essence of his hypothesis is 'what you had is what you get.' Most of the visual changes in boreal mixedwood stands as they mature simply reflect different growth rates of species. Often there is no succession in the tree stratum because the first generation trees reestablish simultaneously, because there are no replacement species, or because fire returns too soon (Rowe 1961).

Unlike areas farther north in the boreal zone of northern Alberta and Northwest Territories, where fires may be very large, burned areas in the mixedwood zone tend to be comparatively small. The excellent fire maps prepared by Delisle and Hall (1987) show that most fires in the Calling Lake–Lac La Biche–Cold Lake region of Alberta between 1931 and 1983 were in the range of 10–30 km in the direction of their maximum extent, in contrast to the Lake Athabasca region of northeastern Alberta where many fires burned for 50 km or more in their direction of advance. The other important feature that has been stressed by all researchers who have studied boreal fire ecology is the relatively short interval between repeat fires on the same area. Delisle and Hall (1987) showed a number of areas in the Lac La Biche region where at least three successive burns have occurred in the 50-year period from 1931 to the early 1980s. There is evidence, however, that these shorter return periods for fires earlier in this century are now being dramatically lengthened as a result of effective fire suppression efforts (to be discussed by Peter Murphy later during this symposium).

Postfire establishment of trees, shrubs, herbs, and grasses by seedling establishment has been recorded by Archibold (1980) and other investigators. There is even more information on postharvesting and postfire vegetative reproduction from underground plant material that has survived the disturbance. The intensity of interspecific vegetative competition after fire or logging is well-documented, and the refinement of boreal mixedwood silviculture does not require more substantiation of this competition; however, more detailed information on the physiology and ecology of the key species involved is of importance. An example is the current set of studies by Lieffers and coworkers at the University of Alberta on the ecology of *Calamagrostis canadensis*. In addition, there is still inadequate documentation on the importance of seedling-origin aspen in stand development and interactions between aspen of seedling origin and sucker origin. It is known that aspen seedlings as young as 1 year old can produce suckers (Farmer 1962); this suggests the importance of improving our knowledge of all aspects of aspen seedling development to complement the excellent knowledge base that already exists for vegetative reproduction by aspen (Horton and Maini 1964; Perala 1972; Schier et al. 1985).

It may be significant for future silvicultural prescriptions in the northern mixedwood region to be aware of the relative proportions of root suckers and root collar or stump sprouts. If mature aspen stems are harvested, the resulting regeneration will be predominantly root suckers. In contrast, if harvested aspen stems are under approximately 20 years of age, the proportion of root suckers decreases because there is a greater abundance of root collar sprouts and stump sprouts (Heeney et al. 1980). This circumstance may be of silvicultural significance if stands were to be harvested on short rotations of 25 years or less. Furthermore, the problem of matching the rotation ages of aspen and white spruce, so that both species would be harvestable at the same time, may be addressed some day by removal of the aspen component when it is 25–30 years old, leaving a spruce component that would be joined by a new aspen crop of vegetative origin and of an age somewhat younger than the spruce saplings[2]. If this approach were to be tried, even on an experimental basis, it is likely that the new aspen stand that results from removal of 25- to 30-year-old aspen would contain a high proportion of stump sprouts or root-collar sprouts, a reproductive method that gives a more clumped distribution than is the case with root sucker regeneration.

Silviculturally, it is important to focus on ecological events in the first 10 years of stand development (Fig. 2). The aspen height growth data in Figure 2 are derived from Bella and De Franceschi (1980) and the white spruce height data refer to natural seedlings in Alberta as measured by Hellum (1978). The dynamics and the interspecific competition associated with these two height-growth curves are well known to northern mixedwood silviculturists. Of more importance to forest managers and to participants at this symposium is the search for new ways to meet the three hurdles faced by white spruce in the first one or two decades after seedling establishment. These three hurdles are represented by the A, B, and C lines in Figure 2. Hurdle A is derived from information summarized by Johnson (1986) and is an estimate of the height that spruce must reach before it can satisfactorily respond to a single release treatment of aspen removal. Hurdle B refers to the height at which white spruce remains susceptible to browsing by snowshoe hares (Johnson 1986; Radvanyi 1987). Hurdle C, at 1.2 m, represents the common maximum height of *Calamagrostis canadensis* which is a very effective competitor with white spruce on the best sites (Haeussler and Coates 1986). The A, B, and C markers, which we may designate as the "Aspen", "Bunnies," and "Calamagrostis" hurdles, are the three main barriers that the northern mixedwood forest manager faces today. They remain as the key challenges for more sophisticated mixedwood management, although I expect that we will also be hearing about other challenges that may appear as D, E, and F hurdles on future summary charts of this kind.

In summary, the northern mixedwood region is dominated by young ecosystems. They are young in two contexts. First, the return period of fire is sufficiently short that the entire mixedwood zone is dominated by forest stands that are young in comparison with stands in many other forest regions of North America. For example, during his work in the boreal and mixedwood forests of the prairie provinces, Rowe (1961) never recorded any type of spruce stand that in structure or condition of humus layer would suggest a third- or fourth-generation spruce forest. Irregular-structured, hummocky-floored stands that indicate successive generations of white spruce can be observed in the more humid parts of the eastern Canadian boreal forest but are not present in the western parts of the region. There may be some examples in the western boreal region of fireproof peninsulas in lakes or on islands in lakes where spruce climax can occur, but these examples are poorly documented.

The second reason why we are dealing with young ecosystems is that the main silvicultural challenge occurs in the first few years after disturbances, as summarized in Figure 2. This is typified by dominant species such as fireweed, willow, alder, *Calamagrostis,* and a variety of other agressive pioneer species that provide substantial interspecific competition. These young ecosystems are characterized by high growth rates, high production, and relative instability when contrasted with mature ecosystems.

The information summarized in this paper has highlighted the importance of events near ground level. The northern mixedwood region is one in which silviculturists will need to focus on the dominant influences and main problems by looking toward their boots instead of to the tree tops. Some of the dominant ground-level influences were singled out by Stan Rowe over 30 years ago: the influence of fire severity in providing either mineral soil or scorched humus as a seedbed for white spruce; the importance of decayed wood on the forest floor as a favorable medium for germination and early growth of white spruce; the burying of young spruce seedlings by leaf litter from aspen and shrubs; and the effects of snowshoe hare browsing of spruce seedlings and saplings (Rowe 1955).

An additional reason for northern mixedwood foresters to look toward their boots is that this downward view focuses attention on another set of important ecological relationships taking place in the root systems

[2] Personal communication, 1988, from S. Ferdinand, Alberta Forest Service, Edmonton, Alberta.

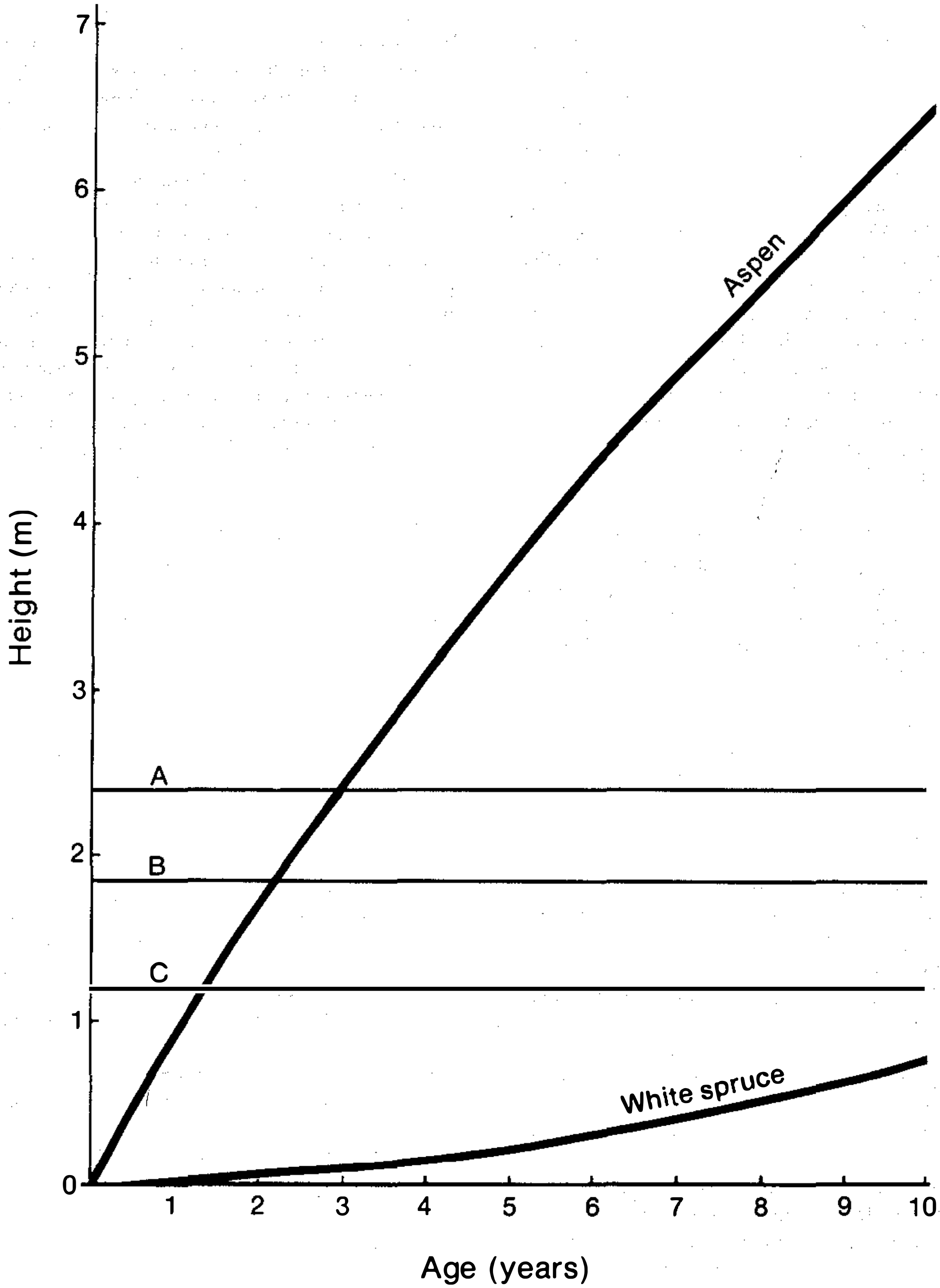


Figure 2. Height of Alberta and Saskatchewan aspen suckers (Bella and De Franceschi 1980) and wild seedlings of white spruce in Alberta (Hellum 1978) during the first 10 years of mixedwood stand development. White spruce does not respond to a single treatment for release from aspen until the spruce is at least 2.4 m tall (Hurdle A, Johnson 1986); browsing by snowshoe hare is significant until white spruce seedlings are approximately 2 m tall (Hurdle B, Johnson 1986); competition from *Calamagrostis canadensis* is significant until spruce exceeds the maximum height (1.2 m) of *Calamagrostis* (Hurdle C, Haeussler and Coates 1986).

of these ecosystems, a subject that we could not begin to unravel here. Root excavation studies near Lesser Slave Lake (Strong and La Roi 1983a,b) have yielded information that silviculturists have yet to appreciate or apply. Their demonstration that aspen and jack pine roots are confined to mineral soil horizons whereas white spruce, black spruce, balsam fir, and larch roots are concentrated in the organic soil horizons is an example of the kind of ecological information that mixedwood silviculturists will need to consider for forest floor management during harvesting and site preparation activities.

Looking to the future, we can expect broader utilization of more of the rapidly growing pioneer species that characterize the northern mixedwood region. Small-diameter woody materials of various species are now commercially viable as sources of cellulose, (Bill Russell will discuss this later in this symposium). This trend extends to nonwoody species as well; in Alaska, *Calamagrostis canadensis* is the most widely used native grass for livestock forage (Mitchell 1987). It is evident that yesterday's weeds may be today's resources. In this context, we all know that Ross Waldron spent much of his early career planning the ultimate holocaust on the lowly aspen. "Frill it to kill it" was one of his mottos. But attitudes change with time—Ross has changed, and our utilization of aspen has changed. Such evolving attitudes, together with changing economic and utilization factors, can be expected to extend to other species in the northern mixedwood region, such as balsam poplar and birch, and perhaps even *Calamagrostis*. We cannot now visualize a use for *Calamagrostis* when it occurs in mixture with aspen suckers or when it is overtopping spruce seedlings, unlike the pure *Calamagrostis* stands that provide livestock forage in Alaska. But history has often shown that today's vegetational curse may be tomorrow's vegetational resource. Future symposia will undoubtedly address this changing utilization scene.

ACKNOWLEDGMENT

Some of the ideas in this review are a result of interviews conducted by the author during a project supervised by M.J. Apps, Northern Forestry Centre, with support from the Federal Panel on Energy Research and Development through the ENFOR (ENergy from the FORest) program of the Canadian Forestry Service. Financial support through that project is gratefully acknowledged.

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THE BOREAL MIXEDWOOD FORESTS OF ONTARIO: PAST, PRESENT, AND FUTURE

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ABSTRACT

The boreal mixedwood is not a rigidly defined forest type in Ontario. Five species—white spruce, black spruce, balsam fir, trembling aspen, and white birch—are considered to be the main commercial species, but jack pine and minor amounts of other conifers can occur. Exploitation of the boreal mixedwood, apart from incursions for local timber use, did not occur until after World War II. The boreal mixedwood has increasingly become a focus from the standpoints of both utilization and silviculture. The present status of both is described together with suggestions for future development in this forest area.

WHAT IS IT? WHERE IS IT? HOW LARGE IS IT?

Eight years ago, a symposium in Ontario had the boreal mixedwood as its topic (Whitney and McClain 1981). In his introductory remarks, G.A. McCormack noted that "it is probably the least understood and most undermanaged forest in the province." One reason sometimes attributed for this is that it is not identified as a separate category in the Forest Resources Inventory (FRI) of Ontario. This, in my opinion, is not so, and this paper will give the basis for my position.

The boreal mixedwood forest is diverse and to a certain degree easier to define by what it is not. It should not be confused with the Boreal Mixedwood Section (B.18a) of Rowe (1972) (the Saskatchewan portion of which has been described by Kabzems et al. (1976)), although they contain many of the same species. In Ontario there are five main component species: trembling aspen (*Populus tremuloides* Michx.), white birch (*Betula papyrifera* Marsh.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), and jack pine (*Pinus banksiana* Lamb.). Typically, mixedwood stands are found on upland soils of various types.

The extent of the mixedwood forest is difficult to determine provincially because the inventory is based on stands identified by the predominant species. These stands are then aggregated into working groups, e.g., poplar working group, spruce working group, and so on. At the management unit level, however, a working group may be subdivided into forest units, which allows for differences in stand composition and other features, including silvicultural practices, to be recognized.

Based on an inventory (Dixon 1963), McClain (1981) estimated that the mixedwood forest comprised 45–50% of northern Ontario's productive forest land. Using data from the Ontario Ministry of Natural Resources (1986), and assuming that approximately one-third of each of the poplar, white birch, and spruce working groups represent mixedwoods, there appear to be about 18% or 7 million hectares of a total production forest, and production forest reserve of 38 million hectares, in mixedwood forests in the province. The volume of growing stock on this 7 million hectares is in the order of 1.0–1.5 billion cubic metres of wood.

ORIGIN AND STRUCTURE

The origin and structure of the boreal mixedwood forests not under management reflect three features: the forests most commonly result from fire, the general upland terrain and soils on which they occur are variable, and the autecology of each of the main component species differs significantly from the others. Taken together, these features ensure that these forests are variable in space and time; this diversity results in profound ecological and forest management implications.

Fire is generally accepted as being responsible for the depletion and renewal of the boreal mixedwood forest prior to human intervention. Certain physical and biological conditions of the forest and its location with respect to climatological conditions affecting fire frequency are important to determining the fire cycle or rotation. In northern Ontario this would appear to be of the order of 50–100 years.

Irregular terrain, variation in the nature and amount of the forest biomass, forest floor conditions, soil texture, depth, and drainage all affect and modify the effects of fire on the soil and subsequent revegetation. The intensity of a fire is also dependent on the time of year and related weather conditions in which it occurs. These features, many of which are interrelated, conspire and result in mixedwood forests that are mosaic patterns of vegetation.

The five tree species characteristic of the boreal mixedwood, although quite different in their autecologies, all have the ability to regenerate after fire. The manner in which they do so, however, is distinct. For example, white birch does this by producting prolific amounts of seed that are wind-disseminated, while aspen poplar suckers from superficial roots to a degree dependent largely upon temperature. Black spruce and jack pine rely on semi-serotinous and serotinous cones, respectively, with retention of cones on trees for several years. White spruce and balsam fir are the two species least-adapted to survive and regenerate after severe fires; therefore, their presence in the mixedwood forest is more sporadic, and to a greater degree than the other species, dependent on local conditions of soil moisture and other factors that in general reduce the intensity of a fire.

The dynamics of the development of the boreal mixedwood in Ontario have been described by Day and Harvey (1981). Essentially, the sequence following fire is for the pioneer species of poplar, white birch, and jack pine to establish and grow rapidly. Black spruce may be in the first group but, together with white spruce, is more usually successional and present in the understory initially, and indeed for many decades. Balsam fir is another successional and understory species whose occurrence is very much linked to the spruce budworm (*Choristoneura fumiferana* Clem.). Another feature of the mixedwood forests are the species of lesser vegetation, particularly shrubs such as beaked hazel (*Corylus cornuta* Marsh.) and mountain maple (*Acer spicatum* Lam.); together with nonwoody vegetation these plants can provide either a beneficial modification or competition-in assisting or minimizing establishment and growth of the tree species. Figure 1 illustrates the age-class structure of a 75-year-old stand after fire in northern Ontario.

THE PAST AND THE PRESENT

Two factors have played an important part in determining the past and present utilization of the boreal mixedwood. Consequently, these same factors have provided opportunities for management of this forest, since implementation of management and silviculture almost invariably follow initial exploitation of the natural forest, and for good reason. Whether the opportunities are embraced is another matter.

The first factor was that the major forest industry development in the boreal forest was the pulp and paper industry, which preceded by many decades the sawmilling industry. The period of development began in the early 1900s, with a burst in the 1920s. One of the first surveys in northeastern Ontario was that of Fernow (1913), who traversed the Grand Trunk Pacific Railroad for 200 miles and concluded that only 10–15% of the area was fit for logging and that the majority of the area contained only pulpwood forests. There was, of course, local sawmilling taking place but this was essentially on a small scale designed to meet immediate and local needs.

The second factor, and tied to the first, was that the technologies of the period for pulp and paper mills required electrical power and water. Further, the most economical means for transporting the wood to the mill was by water. Thus, large rivers were essential as a source of hydroelectric power and for river drives of wood. While the mills' products were transported by rail, access to the woods and supply of pulpwood were seasonal and by tote roads or water. The main species for pulping was spruce, mainly black, and therefore woods operations were concentrated in those forest lands on which such stands predominated.

For these two reasons, therefore, entry into the boreal mixedwood forests for logging and management did not occur until after World War II. Indeed, the necessary precursors to management of a forest—inventory, necessary professional knowledge, expertise, equipment, and clear objectives for management with associated commitment—did not exist prior to then. The postwar inventory with its ongoing 20-year cycle and the implementation of silviculture in northern Ontario since 1960 have become important in providing a basis for management. But the most consequential factor has been the setting in place of all-weather roads for both access and transport of wood. This has resulted in both year-round activities and the availability of wood from mixedwood stands to an extent not possible before. The preferred locations of the roads have been on uplands, where such stands have often been found. Rapid development of sawmills and, to a lesser extent, veneer mills took place, supported by the establishment and opening-up of crown management units, primarily to supply mills other than pulp mills from the 1950s onward.

Increased sawtimber availability is reflected in the increased production of lumber. Between 1946 and

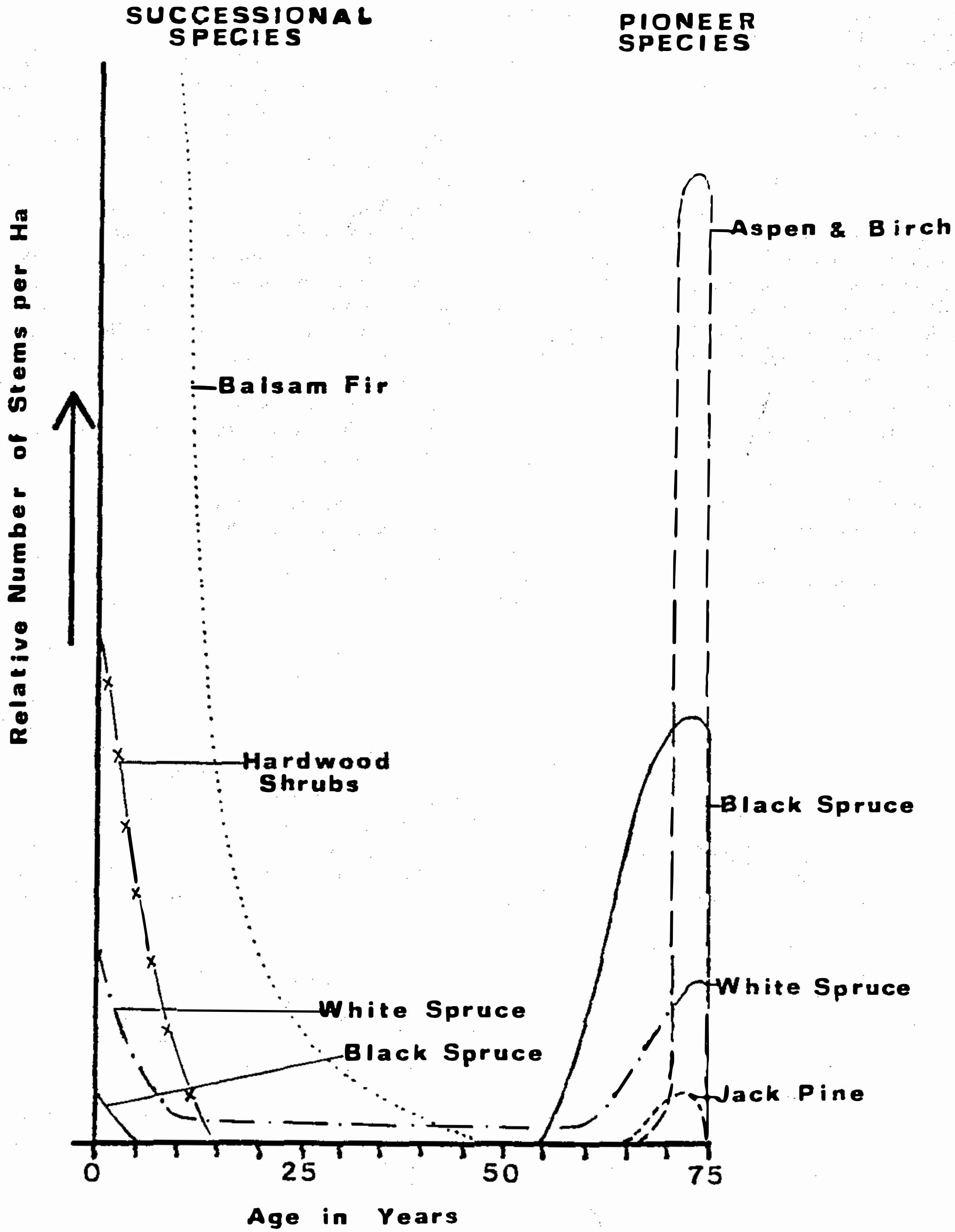

Figure 1. Stand structure of a 75-year-old boreal mixedwood forest in northern Ontario.

1966, total production in Ontario averaged 765.4 million board feet; from 1967 to 1976 it averaged 984.5 million, and from 1977 to 1986 it nearly doubled to an average annual amount of 1756.4 million board feet. Depending upon the year, the amount of hardwood lumber in this total varied between 10 and 25%, but did not contribute significantly to the overall increase.

Changes in mill technology, in both pulp and nonpulp establishments from the 1960s onwards and especially since 1975, have resulted in a competition for the same species and sizes on a scale not seen before, though increasingly, this is being mitigated by exchanges of logs and furnish. Mill demand has also resulted in the utilization of poplar and white birch to an increasing level. For crown forests the amount of poplar harvested increased from 687 164 m^3 in 1976 to 2 768 308 m^3 in 1986, and white birch from 61 504 m^3 to 253 340 m^3 in the same period—both four-fold increases.

Silvicultural practices developed in the 1960s and early 1970s for the most part concentrated on regenerating jack pine and spruce on accessible logged sites. These were areas that had supported conifer stands, and successful establishment of the new forest depended to a great extent on the amount of competing vegetation and concomitant tending. Successes were much greater where soil conditions did not favor such competition. Some of the earliest plantings of white spruce in partially cut mixedwood stands where overstory and understory competition were both present showed the problems of survival, let alone growth. For these reasons priorities in silviculture tended to be other than the treatment of mixedwood stands.

The net result has been that while the overall productivity of the mixedwood forest has been recognized, our ability to deal with it from management and silvicultural standpoints has not been satisfactory. Attempts to convert these stands to a conifer working group have been costly and only partially successful (Puttock and Smith 1987). Certainly, increased if not total utilization of the original stand is paramount. Site preparation using a combination of chemical and mechanical treatments, or prescribed burning with mechanical treatments, is mandatory for any success. Even with this, follow-up tending treatments are usually necessary. The lack of initial stand uniformity and resultant residual slash make the use of prescribed burning much more difficult, even though it has been one of the most successful means of controlling poplar regrowth and removing balsam fir. The natural variability in soil conditions and terrain reduce the effectiveness of mechanical equipment and this, together with any clear and quantified set of management objectives, will reduce the possibility of success.

It could be argued that the forester must develop silviculture that will recreate a stand similar to the natural one that was harvested. As was noted in the previous discussion on the origin and structure of these forests, their composition at any one time is a function of any number of factors and therefore one of virtual happenstance. There is therefore nothing to be gained, for any inherent ecological reason, by attempting such a repetition. From a timber perspective, management of these stands is complicated by the biological differences among the species. Mean annual increments for poplar and white birch culminate at approximately 50–55 years, while spruce reaches a maximum at 90 years. Jack pine is intermediate at about 60–70 years. These rates will vary with site conditions and level and type of management treatment. The result is that foresters are more often than not in a quandary as to how to proceed.

A complicating factor in stands where balsam fir is a significant component is the matter of dealing with the spruce budworm. Where stands are mature or nearing maturity and the fir can be utilized, protection and salvage are the standard practice. Barring any other treatments, this will normally result in a stand with an equal if not greater amount of balsam fir. The white spruce component is reduced by both the removal of mature trees that could be a future seed source, and also by the fact that any residual spruce will have reduced seed supply as a result of the budworm attack. For stands with a spruce–balsam fir component, Gordon (1985) has suggested that the budworm be allowed to run its course and remove the fir, and that over time the spruce component will increase. Any subsequent tending in these stands to reduce overstory poplar and white birch would presumably enhance the growth of the spruce.

THE FUTURE

It is axiomatic that if you do not know where you are going, you are more likely to wind up in places you would rather not be. When stands of one dominant species are to be harvested, the decision as to what the new stand should be is usually not too difficult and regenerating the stand in the most effective manner is usually straightforward. With mixedwood stands, the decision is not so easily made.

A clear statement of the objectives of management is necessary but cannot be made in isolation from the knowledge base of the inventory. I am assuming that well-tried silvicultural practices for the treatment of mixedwood stands are not available yet. On this basis, future progress would appear to lie in the following directions:

1) Mixedwood stands must be segregated into two basic groups, one consisting of stands eligible for harvesting in the planned future, the other of stands of intermediate development that will not be harvested for several decades.

2) A further subdivision must be made within each of these two groups on the basis of species composition, growth, and soil and site characteristics. With such a breakdown of the mixedwood stands, a strategy could be developed taking into account current utilization and market demands. This would also provide a basis for identifying stands for future utilization, including increases or decreases in demand for different species.

3) The differential in growth rates of the species means that attention will have to be paid to the rotation ages and harvesting method to a much greater extent than before.

4) There is a need to develop silvicultural treatments and equipment suited to variable stand conditions, in particular variation in soil conditions and topography.

What is really needed is a much more sophisticated development of silviculture in both planning and implementation that contains a major component of natural regeneration, complemented in required situations by artificial regeneration.

None of these four suggested directions is novel, but to a large degree, advances in our silviculture have resulted from a large number of attempts, usually on a hit-and-miss basis. This has been reasonably successful for essentially monolithic stands, but I don't believe we can afford that approach with our mixedwood forests. They are generally very productive and provide for diversity, and hence the opportunities for greater management flexibility.

In terms of nontimber values and uses the mixedwood forests are becoming increasingly important, and it behooves foresters to develop silvicultural treatments that can better provide for them. The boreal mixedwood presents the greatest challenge to Ontario foresters silviculturally for the next few years. Time will tell whether we have risen to it.

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BOREAL MIXEDWOOD MANAGEMENT IN MANITOBA—THE PAST IN PERSPECTIVE

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INTRODUCTION

The true mixedwood forest region in Manitoba covers only a very small portion of forest land in the western area of the province. This subregion of Rowe's (1972) classification of forest regions is part of the expansive Boreal Forest Region. The management of the mixedwood forests and the species in this area has been, in many respects, the same as the management of those same species throughout the other important boreal forest subregions in Manitoba. These include the Lower English River, Manitoba Lowlands, Aspen–Oak, Aspen Grove, Nelson River, and Northern Coniferous. These species are also found in the Great Lakes/St. Lawrence Forest Region (Quetico and Rainy River subregions). There are two or three other subregions within the Boreal Forest Region that are not referenced, because the forests they contain are not considered to be commercially important.

The species within the subregions mentioned are generally few in number and vary in both quality and quantity. They do, however, occur both in mixtures and in pure stands and therefore, I believe, must be considered in the discussion today. The mixtures referred to are both softwood (conifer) and softwood/hardwood (deciduous) mixtures, and most of my references with respect to the latter are in the context of the trembling aspen subtypes. Management of the species has, for the most part, been singular in objective with some minor variation depending on local demand by the forest industry. The species (Hosie 1969) are black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Ait.), balsam fir (*Abies balsamea* (L.) Mill.), eastern white cedar (*Thuja occidentalis* L.), tamarack (*Larix lariciana* (Du Roi) K. Koch), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.).

STAND MANAGEMENT

As has probably been the case in many provinces, stand management has been as much as anything a case of trying to reproduce the same forest, and more particularly, the species that was harvested. In some cases, the management strategy has been basically to do nothing and let nature take its course. This would produce or create a situation where successional changes took much longer, if in fact they ever occurred, than would be the case following wildfire. Because most of the species referenced are fire-successional, forestry and forest management, in my opinion, are nothing more than different forms of farming in many respects, and, as any western Canadian farmer will tell you, the costs of farming are significant. While the management of forests is generally thought to be the mandate of professional foresters, all too often in the past that mandate has not been supported by the industry with which foresters are employed or the government and public who own both the land and the forest resource. This type of stand management, that is, the "do nothing" approach, has also resulted in, for the most part, lower-grade stands in which commercially important species are found in very few numbers, if at all. Manitoba's forest landscape is covered with a number of forest areas where the "do nothing" approach has resulted in forests of low quality. The costs of doing something now, that is, to put these back into a highly productive state, are significantly higher than if it had been done immediately following harvest. True, advances in today's technology may in some instances make the job easier to carry out, but even that ease can be a fairly costly proposition. Harvesting techniques have similarly changed and perhaps in many ways for the better. The historical situation, however, has not likewise always been supportive of good and professional forestry practices.

TIMBER HARVESTING

Let us examine harvesting practices in Manitoba that have taken place in the past. Harvesting has for the most part been carried out as a result of a quest for a specific species or size of timber, and softwoods were by far the most important species group. Successful regeneration and forest renewal of some harvested areas resulted more from accident than by design or specific harvesting techniques for the express purpose of ensuring regeneration. Harvesting techniques (and this is still true to some extent today) were guided more by existing markets—the supply of the timber and the demand for it—and, without question, economic considerations.

There were exceptions of course, and professional foresters in attempts to practice their training, did make some valiant efforts toward tying harvesting to forest renewal, often with success.

Let us briefly look at the situation of some of the major commercially important species. Black spruce has been harvested on a clear-cut basis. Depending on the particular subregion, and taking into consideration climatic factors and site productivity, varying degrees of reproduction of the species have resulted. The clear-cutting was generally limited to portions of the stand that contained larger timber of economic size. Thus, the clear-cuts were really edge cuts around perimeters of stands or, if by chance the entire stand consisted of trees of the same size, a true clear-cut was experienced. Regeneration in the case of the latter harvest was not as spectacular through natural processes as in the former case of edge cuts, but it nonetheless did occur. Tamarack (eastern larch) regenerated at higher proportions than in the original stand in a number of cases. Controlled burns on these areas also produced an excellent seedbed and good regeneration resulted.

Pure white spruce stands were much fewer in number, but when found were harvested to a minimum diameter limit, thus ensuring that only the larger trees were removed from the stand. Smaller-diameter white spruce remained and continued to grow, but the open stand often resulted in wind damage in instances where pockets of trees above the minimum diameter were harvested on a clear-cut basis. Regeneration of the species did occur if the soil was sufficiently disturbed.

Pure jack pine stands were selectively harvested and only the larger material usable as sawlogs, hydro poles, or other large products were removed. Top material and smaller-diameter trees not suitable for lumber were most often left. Until pulpwood markets for pine began to improve, cleanup of these areas produced a significant problem for foresters attempting to carry out reforestation practices. Generally speaking, natural regeneration did not occur.

Pure trembling aspen stands were harvested in the same manner, with only those trees suitable for match splints and lumber being removed. The general deterioration of the stand occurred on an increasing basis with successive selective high-grading cuts. Stands regenerated naturally but the degree of suckering was dependent on the number of stems removed in the initial cut, the size of the openings, and the amount of slash or logging debris remaining on the area.

The harvesting of species mixed with one another, whether softwood or hardwood–softwood mixtures, was also extremely dependent upon the markets that existed. For the most part the degree of utilization of all conifer species in the stand was dependent upon a strong pulpwood market, the exclusions of course being tamarack and cedar. To some extent, problems associated with clear-cutting and full utilization of all conifer species are still dependent upon the marketplace. The pine pulpwood market has improved significantly in the past 10 years, but from time to time there is reluctance to utilize the species in spruce–pine mixtures or, for that matter, in pure pine stands. Mixtures of conifers and hardwoods are even more of a problem. In a majority of instances, the softwood component is removed as are the top-quality trembling aspen and white birch trees used solely for the manufacture of lumber. Beyond this, utilization of the hardwood component has generally never existed. Only for a brief period in the late 1960s and early 1970s in the southeastern region of the province did complete utilization of trembling aspen occur in pure stands or in mixtures.

FOREST RENEWAL

Pure Conifer Stands

Forest renewal efforts in Manitoba date back prior to the transfer of the forest resources to the province by the Dominion of Canada (July 1930). In spite of previous references to "the do-nothing" management approach, there have been increasing efforts made in both artificial and natural reforestation. These originally occurred in natural forest openings on prairie land or on harvested sites that had sat idle until stumps and roots had rotted to allow site preparation equipment to do a satisfactory job. The earliest commercial plantations on record date back to 1903.

Forest renewal efforts since that time have been fraught with numerous problems and the degree of success has without question varied. Early plantations that today appear to have been extremely successful were refilled on a yearly basis three or four times to ensure optimum stocking throughout the life of the stand to maturity. Species requiring site preparation, such as jack pine, red pine, and white spruce, were extremely difficult to establish on freshly harvested sites. Residual stems existed as a result of poor utilization and a lack of markets. In most instances forest renewal did not occur on these sites. In these cases, the residual stand consisted of lower-grade trees and poor stocking generally resulted.

Where true clear-cutting occurred, the lack of adequate site preparation equipment such as we have today also made that task of artificial reforestation a difficult one.

More recently and with the advent of larger equipment, new technology and the more complete utilization of all stems and trees in a stand, greater levels of success have been achieved. This is particularly true in pure pine stands or conifer stands containing mixtures of spruce and pine.

Success has always been achieved on pure black spruce sites under moist to wet soil conditions. The successes achieved were due more than anything to the physical nature of the stands and the type of harvesting techniques used. These resulted in adequate seed sources to ensure natural regeneration of the species. I might say that successful regeneration in these instances was not due to professional forestry planning as much as it was by accident. There were, however, some attempts made by visionary foresters at using harvesting techniques to promote regeneration that proved very successful.

Pure Hardwood Stands

Digressing for a moment to pure hardwood stands consisting mainly of trembling aspen, may I say that planned forest renewal attempts have been minimal. The province has dabbled in several trial plantations of hybrid poplar with varied success. Initially it was thought the fast-growing hybrid might produce sawlog material, and so plantations were established with a rather wide spacing. While some sawlog material may result from the trials, it would appear that the real potential may lie in producing volumes of timber for particle board, flake board, or oriented strandboard products.

As alluded to earlier, Manitoba's trembling aspen working group are those with a predominant trembling aspen component and a varying degree of mixture with other broadleaf species. The trembling aspen has essentially been high-graded for lumber and match splints. I have referenced the resulting stand that this harvesting produced and the difficulty experienced most of the time with obtaining natural regeneration through vegetative suckering. The real potential in managing stands in the trembling aspen working group lies in a true clear-cut with the harvested timber being utilized both for lumber and some form of fiber product. While experience has not been extensive in terms of large acreages in Manitoba, clear-cutting of stands in the trembling aspen working group has occurred. A variety of planned forest renewal treatments have been carried out, ranging from no treatment at all to fairly intensive site preparation to disturb the soil and break up the root systems in an attempt to obtain substantive vegetative suckering. I think it can be safely said that all forms of treatment were successful.

MANAGING THE CONIFER/DECIDUOUS MIXEDWOOD STANDS

Early Years to the Present

Utilization and subsequent management of mixedwood stands are varied. As mentioned earlier, one end of the spectrum involves the harvesting of the softwood component and leaving the residual stand and regeneration to Mother Nature. The other end of the spectrum involves a conscious effort to ensure that the softwood component is regenerated. A number of techniques have been tried and I think there have been some rather astounding successes. On the "do something" end of the spectrum, the treatments have included attempts to introduce a softwood component into a pure aspen stand. These aspen stands either consisted of residual stems resulting from high-grade harvesting or young even-aged stands resulting from fire. The flip side of these treatments has been what might be considered true stand conversion, where poor-quality residual poplar stands were completely removed and replaced with softwood plantings. Follow-up treatment involved the use of herbicides to ensure a good start with the least amount of competition from other vegetation. Having briefly discussed the strategies, now let me deal with some of the specific treatments.

In introducing a softwood component to an already existing hardwood or trembling aspen stand, two basic techniques were tried. In one, a bulldozer cleared 7- to 8-foot-wide strips through a residual trembling aspen stand or through a young stand originating from fire. The strips were then planted with white spruce seedlings, (generally three rows of alternately spaced seedlings within the bulldozed strip), a rather high-intensity planting and spacing. The alternative was to carry out broadcast seeding on these cleared strips. In the older residual stands sometimes a follow-up treatment of girdling the older trembling aspen was sometimes carried out to reduce the shading effect of the older trees, which was particularly heavy in more-dense stands. This unfortunately resulted in fairly significant blowdown of girdled timber.

Other forms of follow-up treatment generally involved generous applications of various repellent products to persuade hungry deer and rabbits that the planted seedlings were not set out for their benefit. This sometimes worked, but for the most part these plantations succumbed to repeated heavy browsing, particularly by rabbits. The south slopes of the Porcupine Provincial Forest and fairly large areas in the Interlake Forest Section have pure trembling aspen stands with rows and rows of strips containing nothing more than raspberries, saskatoons, and a variety of other herbaceous vegetation—lots of deer, but alas, no softwoods. In other instances, successes were achieved and follow-up treatments have subsequently been implemented involving release through mechanical and/or chemical means.

To digress for a moment, I should sound a cautionary note. It is worthwhile to mention that one cannot be too careful in the application of release treatments, as Manitoba's experiences will attest. Plantations quite often released are immediately subjected to frost damage. Another unforeseen problem was white pine weevil attack, which tends to reduce, rather significantly in some instances, gains which had been made. In the case of white pine weevil, further follow-up treatments are necessary to remove the insect. Man-made forests in some cases are very expensive propositions.

Another shelterwood treatment that was applied involved the scarification on the lee side of residual white spruce or black spruce and regeneration by natural seeding. This treatment was applied in mixedwood stands where the majority of softwood had been removed through harvest, and a conscious effort made to retain seed trees. Following establishment of conifer regeneration, residual trees were then removed in a clean-up harvesting operation.

As briefly touched on above, a more-recent management technique was an attempt at complete conversion in residual hardwood stands that were initially mixedwood until the conifer component was removed through harvesting. A considerable area within a 30–40 mile radius of the Abitibi-Price Pine Falls plant in Manitoba has been treated in this fashion. The follow-up treatments consisted of herbiciding and, while one might have thought that the extremely productive sites that were being treated would yield good successes, this has not been the case. The problem appears to have been with the selection of the right black spruce seedling type and seedling quality for sites that turned out to be a rather difficult planting chance. Nonetheless, the success has varied from poor to moderately good. Growth of seedlings in some cases has been excellent.

The Future and Other Considerations

I think that a new philosophy or strategy needs to be developed for the management of mixedwood stands. I would not pretend to know what the answers are and how that management strategy should be fashioned. I would, however, say that I believe that for some time to come conifers or softwoods will still be of interest to the forest industry. Continuing consideration therefore needs to be given to the management and renewal of the softwood species, either in pure or mixed softwood stands. As a viable component to the mixedwood subtypes where hardwoods are also found, a greater level of attention will have to be given to sound and economical techniques to ensure the softwood component is maintained.

Recently I had the most enjoyable opportunity to listen to Alvin Toffler, one of several keynote speakers at a conference in Los Angeles. Toffler, the author of *Future Shock* and *The Third Wave*, made a number of very interesting observations in his address. Several of these come to mind now. He said that we should be cognizant of patterns of the past in dealing with the future. We should recognize that change is always occurring, he noted, and I think that in most cases we do recognize this in the forestry sector. Toffler also said that sometimes systems are stretched and therefore do not always follow what we consider to be the normal patterns. In other words, there is no straight line projection from past to future, according to Toffler. This applies to the continued use, in our case, of softwoods and what we currently think of as standard softwood products.

In planning for the future, we as foresters might consider Toffler's observations on high-low probability and impact. Normally we tend to think of potential occurrences, opportunities, or situations in terms of high probability. Generally, the impact of these in respect to immediate change on society, or in our case, the forest industry, is quite low. It was Toffler's contention that we ought to spend more time thinking about those low-probability occurrences, issues, or opportunities that result in extreme impact change. He, of course, suggested examples that were more global in context: a reunited Germany with nuclear arms, a split in the Roman Catholic church, a Mexican insurrection and its impact on Texas and California. A low-probability event that comes to mind in forestry is the complete utilization of our hardwood resource in Canada, specifically trembling aspen, and a decline in the demand for softwoods. Perhaps this trend is already occurring. Twenty-five years ago one would have thought the probability to be low, but the impact is high in respect to current nursery operation, production, and configuration.

The strategy will have to be cognizant of what appears to be an ever-increasing interest in the hardwood component of mixedwood stands. With this in mind, foresters should begin to factor the "what if" situation into their planning. While being primarily interested in the production of wood and wood fiber for processes requiring more of the hardwood component, we should be conscious of other considerations that will have to be kept at the forefront of our management techniques. For example, I refer to an ever-increasing need to be cognizant of the needs of wildlife managers and a proper balance of mixedwood stands that are required to ensure healthy and viable wildlife resources.

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THE PAST IN PERSPECTIVE: THE NORTHERN MIXEDWOOD FOREST IN ALBERTA

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INTRODUCTION

History and nature created the forests we are managing and harvesting today. Forest fires were the creators of most of today's forests in Alberta.

SPECULATIVE FOREST FIRE OCCURRENCE

To review historical forest fire occurrence before 1920 one has to analyze the current age class distribution of the forest growing stock to derive a somewhat speculative appreciation of fire's influence.

Excellent age class data were available for a 7770 km² (3000 sq. mi.) Forest Management Area forest in Alberta; it was used as the analysis model. The data results were applied to the 19.2 million hectares of productive forest area in Alberta to speculate upon historical forest fire occurrence (Fig. 1).

Figure 2 shows the percentage of forest fire burn area by age class related to the percentage of forest growing stock volume by age class in Alberta. (Burn area data are from Figure 1, while growing stock volume data are from page 13 of *Alberta Phase Inventory: An Overview* (Alberta Forest Service 1985).) To a significant degree, Figure 2 confirms that forest fires created our current forests and their age class distribution.

Figure 3 shows actual forest fire occurrence in Alberta for 1920–85; it also shows the timber harvest trend during this 65-year period. Some significant forest management developments are highlighted in Figure 3. It should be noted that Alberta was still experiencing severe timber losses to forest fires as late as 1940–49.

Timber harvesting in the 1940s was associated with coniferous species utilization for railway tie and lumber manufacture. Felling utilization was normally prescribed to a minimum 10-in. stump diameter. Large areas of cutover resulted, and they supported a degraded residual stand into which coniferous species regenerated in clumps and patches. In some cutovers, heavy regeneration of poplar occurred, and some of these stands today form our mixedwood forest.

Poplar species were underutilized in Alberta until about 1983. The pulp companies that established mills in the 1950s and 1970s found they could not utilize poplar as pulpwood furnish because it reduced the runability of the pulp-forming machine and customers wanted a price reduction for pulp containing hardwood.

ALBERTA'S FORESTS TODAY

The influences of historical natural changes on Alberta's forests are evident in the forests today. Table 1 indicates that all 10 provincial forests support a varying percentage of mixedwood and pure deciduous growing stock. The Slave Lake Forest has the largest deciduous volume component, and the Edson Forest has the smallest.

Pure deciduous stands occupy 35% of the productive land area; often these stands support a coniferous understory. Mixedwood stands occupy 18% of the forest

Table 1. The mixedwood–deciduous forest area of Alberta as a percentage of the productive forest land

Forest	Total productive area (km²)	Percent mixedwood–deciduous area
Bow–Crow	8 967	21.0
Rocky	11 836	26.5[a]
Edson	15 996	19.7[a]
Whitecourt	15 457	47.7[a]
Grande Prairie	18 593	62.5[a]
Slave Lake	29 118	74.5[a]
Lac La Biche	14 790	54.5
Peace River	24 909	71.8
Athabasca	21 901	39.5
Footner Lake	30 225	64.8
Total	191 792	
Average		53.7

[a] Deciduous harvest occurring.

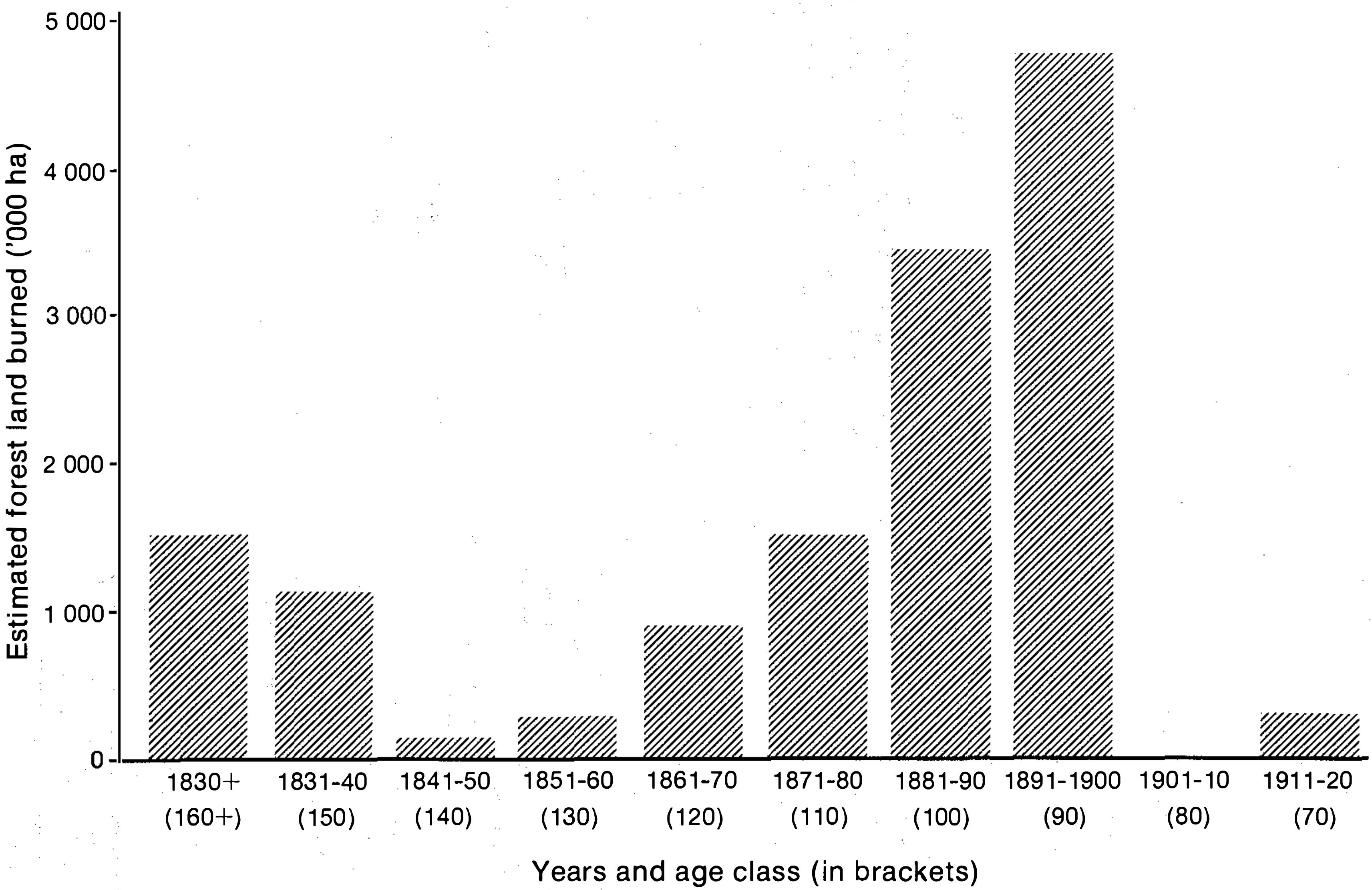

Figure 1. Speculative forest fire occurrence in Alberta based on 19.2 million hectares of productive forest area managed.

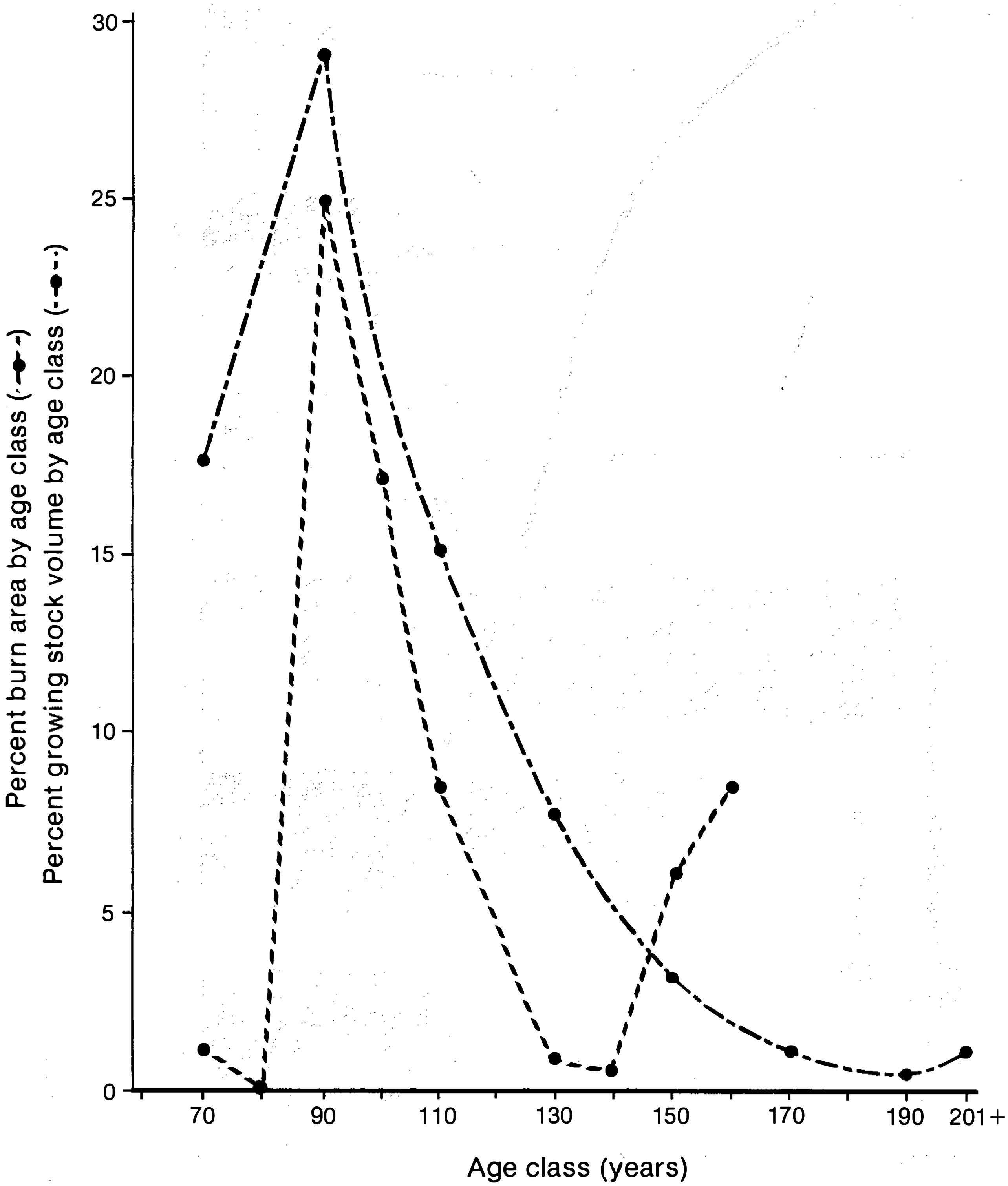

Figure 2. Percent burn area by current age class versus percent growing stock volume by current age class in Alberta.

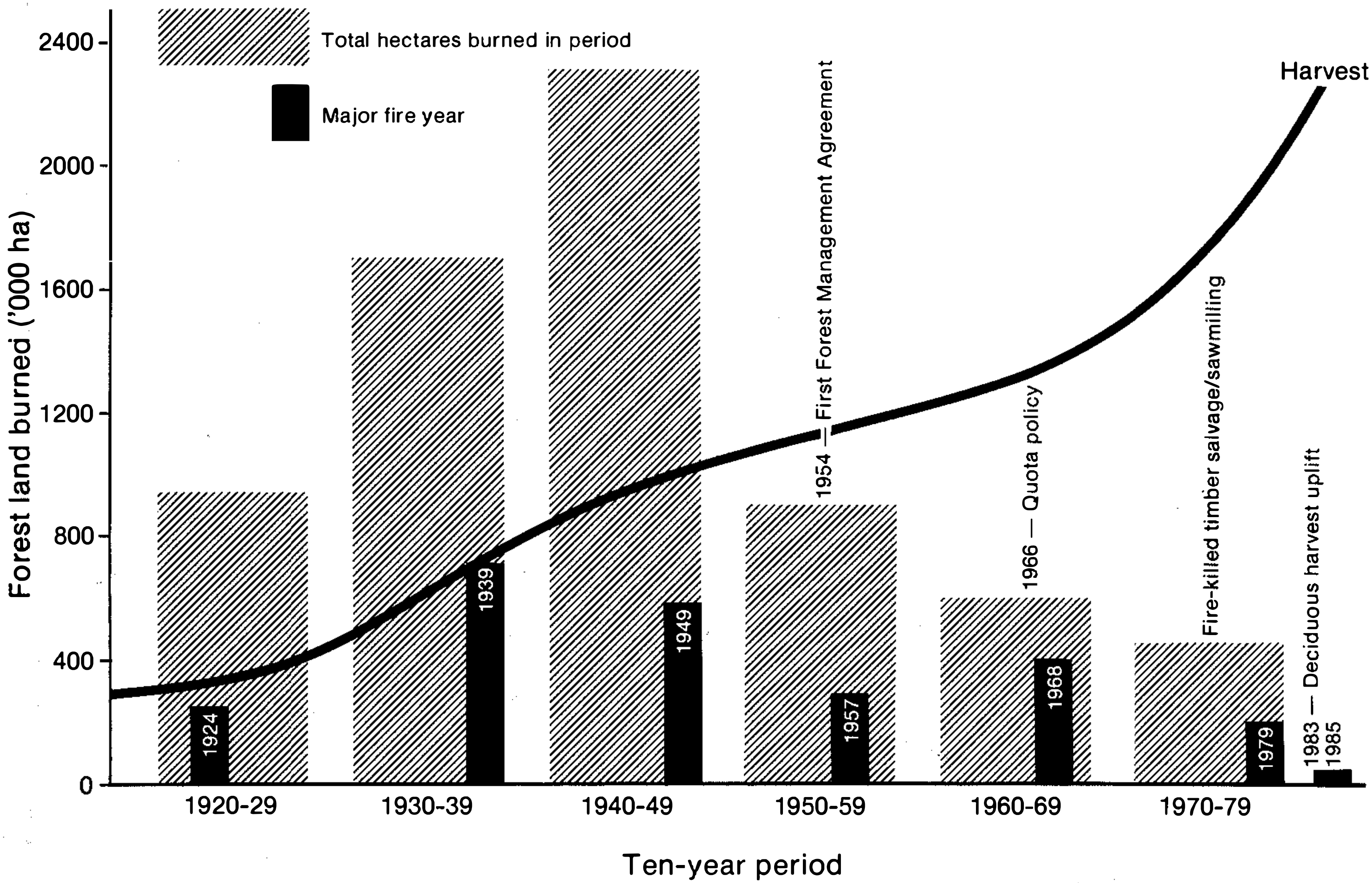

Figure 3. Historical forest fire occurrence and timber harvest in Alberta.

land base. The hardwood species in Alberta therefore occurs on a total of 53% of the land areas.

The situation of forest renewal after harvest in the future can be one of extreme difficulty if we do not apply simple and realistic standards of species restocking. The harvester of only hardwoods should have a piece of cake for stand renewal if he can avoid harvest of mixedwood forest.

The harvester of both hardwoods and softwoods can have a resource manager's nightmare of renewal of preferred species—sometimes by decree. As well, the harvester of softwoods only already has the nightmare of forest renewal of conifers as he fights to eliminate the competition from hardwood regeneration. The *Alberta Timber Harvest Planning and Operating Ground Rules* (pages 17–19, Alberta Forest Service 1987) already recognized the problems of dual-species management and renewal.

I leave you with two questions:

1) Should we emulate nature by encouraging more mixedwood forest occurrence?

2) Should we battle nature by discouraging mixedwood forest expansion?

The answers are what we are seeking in this symposium.

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POLICIES AND PROGRESS IN THE UTILIZATION OF DECIDUOUS SPECIES IN B.C.'S NORTHERN INTERIOR OR "THE BRITISH COLUMBIA ONE-STEP"

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I appreciate the opportunity to participate in this symposium addressing the management and utilization of northern mixedwood forests. I especially looked forward to visiting Alberta and seeing some of my Alberta friends again. While Albertans may look upon British Columbia as a province of volatility, controversy, and conflict from time to time, we on the other hand look upon Alberta as Canada's most conservative province. In fact, it has been said that Alberta is so conservative that even its female impersonators are women.

The task that was given to me was to review the past policies and utilization trends with respect to British Columbia's northern mixedwood forests. I have defined the part of B.C. that is pertinent to the subject as being the northern half of the province's interior forests. More specifically, it comprises the entire Prince George Forest Region and the interior component of the Prince Rupert Forest Region.

I intend to spend a little time in reviewing the past trends in the utilization of British Columbia's deciduous species. After all, it was the problems associated with the utilization of aspen, birch, and cottonwood that created the problems associated with the utilization of British Columbia's northern mixedwood forests. Following this I will spend most of my time discussing forest policies and utilization trends of the past 10 years—the era of greatest change in the utilization of British Columbia's northern interior deciduous species.

Like elsewhere in western Canada, the utilization of deciduous species in B.C. has not been a continuous and unbroken success story. Just as western hemlock was considered to be a "weed tree" during the early years of logging in B.C.'s coastal forests, lodgepole pine was largely considered to be in the same category as recently as the late 1950s. Thus, it should come as no surprise that British Columbia's deciduous species have not been viewed as having much, if any, commercial value until recent times.

Of course, there has been some use of red alder, birch, maple, and cottonwood in the accessible lower coast forests for years, but, apart from firewood use and the involvement of one company in the management and use of black cottonwood, one cannot describe the use of deciduous species in the coastal forests as anything but modest at best. The recent announcment that a chipping plant is to be built in the greater Vancouver area to utilize deciduous species may change this utilization picture in a positive manner.

If the history of the utilization of deciduous species in British Columbia's coastal forests has been modest, the record in the interior forests is even less encouraging. Granted, black cottonwood has had a history of utilization in some parts of north-central and northern B.C.; however, the range of the species is restricted to valley bottoms and overall it is but a minor component of the deciduous resource of B.C.'s northern forests.

Of course, aspen is the main deciduous species in the area. Because it was the species in least demand and often comprised the major component of mixedwood stands, restrictions pertaining to the logging of mixedwood stands were introduced early. In effect, logging was prohibited in those mixedwood forests where aspen was the major component, unless the aspen was to be utilized. Because the coniferous component of these mixedwood stands was of a fairly young age, it was rationalized that these forests could be deferred from logging with no volume loss to the coniferous component until some future time when the aspen would be considered merchantable. Notwithstanding this policy of constraint, mixedood stands that were approved for logging because of a greater coniferous component resulted in a residual stand of aspen that provided no little challenge to the silviculturists of the day.

Simultaneously during this period, attempts were made to foster the utilization of deciduous species (i.e., aspen) in British Columbia's northern interior forests. These attempts included initiatives such as the following:

1) Pressure was put on the companies operating pulp mills in the Prince George–Mackenzie area in the early 1970s to utilize the deciduous component in the companies' coniferous cutting permits. While the deciduous component of these cutting permits was

usually minor, it was rationalized that the pulp mills should be able to incorporate 1-2% deciduous chips into their chip intake. Although a few companies incorporated some aspen chips on an experimental basis, controversy immediately arose with respect to customers' demand for pulp containing no deciduous component whatsoever.

The brewing utilization controversy was short-lived, however, as British Columbia's northern interior was in the midst of a rapid transition—from a period of acute shortage of sawmill-generated coniferous chips to one of surplus—with all of its attendant problems. With surplus coniferous chips being burned or otherwise destroyed due to a lack of domestic or export markets, it made no sense to continue with the pressure to utilize a component of deciduous chips in the wood supply for the local pulp mills.

2) Of course, there was the usual number of entrepreneurs promoting projects relating to the use of the area's deciduous species. While some deserved serious consideration, others were promotional packages to the extreme. An example of the latter involved the use of aspen chips for cattle fodder—a proposition in itself that had been shown to have some promise. In this case, however, the applicant stated that he required a major allotment of coniferous cutting rights so he could first build and operate a modern sawmill and veneer plant.

3) Several small sawmills were established to cut aspen and birch lumber and studs. Upon their request, most were given small timber sales over deciduous timber to assist in the start-up transition period. To my knowledge, all of these sawmills either faded away due to being uneconomic or else ended up sawing coniferous species.

4) Two veneer mills did get established in the northern interior where the original objective was to utilize a major component of cottonwood. In both instances, the major wood supply ended up being coniferous species, although some cottonwood continued to be used.

Thus, the past use of the deciduous component of British Columbia's northern interior forests, whether in pure or mixed stands, is far from being considered a success story. In fact, the history could be dubbed "the British Columbia One-step"—three steps forward and two steps backward. In fact, "the British Columbia One-step" should only be attempted with the utmost concentration because the steps are intricate. As a result, one can readily become confused when it comes to the utilization of deciduous species and unwittingly fall into the "two steps forward and three steps backward" version.

It is with this background that I would now like to discuss the most recent era of deciduous policies and utilization of British Columbia's northern forests—an era in which considerable progress has been made in a very short period. In fact, at the next "Deciduous Ball" the feature dance may well become "the British Columbia Three-step"—three steps forward and no steps backward.

The year 1979 was a significant year in this era of positive change. It was in that year that the governments of Canada, Alberta, and British Columbia cosponsored a symposium similar to the one that we are involved in today. It was convened in Prince George, B.C. on November 21-22, 1979, with the theme "Utilization of western Canadian hardwoods" (McIntosh and Carroll 1980).

The introduction to this symposium acknowledged that although hardwood species are a minor part of British Columbia's forest resource, they are a major component in specific areas of the province. Further, the foreword in the published proceedings stated that

> Over the years, many attempts have been made in western Canada to produce and market hardwood products, but with little success. Softwoods are too readily available. However, as the softwood resource approaches the limits of allowable cut, the importance of the hardwoods in meeting future demands is increasing.
>
> The utilization of this resource is of growing concern to both government and industry, as it represents the potential for an expanded forest industry.

While the 1979 symposium addressed utilization of all western hardwoods, B.C.'s aspen resource received some specific attention.

What came out of the conference with respect to aspen?

1) We learned that less than 4% of the total volume of timber in the B.C. interior was hardwood.

2) We learned that over two-thirds of the B.C. interior hardwood resource was aspen.

3) We learned that this percent rose significantly as we moved northward (east of the Rocky Mountains). In the Fort Nelson Timber Supply Area, for example, it comprised approximately one-third of the forest inventory.

Obviously, we could see that if we had a hardwood utilization problem in the B.C. interior, it was primarily an aspen utilization problem. At that time the harvest of the deciduous resource was negligible. What was even more distressing was the fact that during the extensive agricultural land clearings under way in all northern B.C. before and during this period, virtually all deciduous species ended up in windrows and were destroyed.

That symposium addressed a number of key issues, including:

- the need for an improved inventory of the deciduous resource;
- the need for silviculture guidelines for deciduous species;
- the need for market promotion;
- the need to address the pricing of the deciduous resource; and
- the need to look at government policies that might be a disincentive to the utilization of deciduous species, especially in the determination of allowable annual cuts.

A postsymposium committee looked at these challenges. Important as the remainder were, the group decided that the following three deserved priority at the time: marketing of the interior's deciduous resource; pricing of the interior's deciduous resource; and removal of any government policies that might be disincentives to the utilization of deciduous species.

Let us look at where we are today in the context of the 1979 symposium results and how the three major priority challenges were addressed.

The marketing subject was considered to be the prime challenge, albeit it was hoped a surmountable one. High transportation costs due to the location of the major component of the aspen resource in the northeastern part of the province were all too obvious.

Because the marketing subject would be a symposium in itself, I will not pursue it much further except to state what action was taken. The governments of Canada, Alberta, and British Columbia agreed to fund a project to address the aspen marketing challenge and to take appropriate steps to pursue the appropriate recommendations. The report prepared by a consultant was completed and published.

The second challenge was the pricing of the resource. At the time, deciduous stumpage was low and was not considered a major impediment in developing increased interest in the utilization of B.C.'s deciduous resource. Nevertheless, it was important to look at all possibilities if we were to start using a resource that was being wasted and destroyed.

The then-Minister of Forests, the Hon. T.W. Waterland, presented the opening address at the 1979 symposium. One part of his speech addressed the pricing of the aspen resource. He stated:

> In the short term, because we are so concerned about making full use of the hardwood resources in B.C., the government is willing to consider incentives for the use of aspen. If there is a serious, viable proposal from industry, my ministry will be receptive and prepared to consider incentives such as reduced, very minimal, or no stumpage for aspen.

While recognizing that the stumpage value for aspen and the other interior deciduous species was not excessively high at the time, the postsymposium committee felt that the minister's statement had set the desired tone for initiatives by the private sector, at least as far as the stumpage subject was concerned.

The third challenge was the review of any policy that might be a disincentive to the utilization of deciduous species. In particular, we reviewed the allowable annual cut policy. Up to 1979, all species, regardless of the levels of utilization, had been included in the determination of an allowable annual rate of timber harvest for a management unit—albeit some deductions had been made for merchantability and accessibility factors. The B.C. Forest Service had already recognized that regardless of these deductions, there was a barrier to the full utilization of deciduous while the species was a part of the determined rate of harvest. At best, it was a psychological deterrent; at worst, it was a definite barrier to the utilization of the hardwood resource, especially its aspen component.

The review of the lessons of the 1979 hardwood symposium confirmed this belief, with the result that changes to the allowable cut policy occurred immdiately. In effect, the hardwood resource was removed from the determination of the allowable annual cuts in all timber supply areas and tree farm licenses. Further, it was made abundantly clear to all concerned that private sector proposals for its utilization were welcomed. In view of its percentage dominance, this change in policy was particularly significant for the province's aspen resource and, in particular, to the northeastern parts of the province where the primary aspen resource was located. Of course, it was planned that once the deciduous species were in demand and being utilized, the deciduous and coniferous resources would be treated in a similar manner with respect to rate of timber harvest policies.

While some may not term these actions as incentives, at least two potential disincentives were removed from the utilization of the northern interior's deciduous resource through

1) a pricing commitment by the Minister of Forests; and

2) a releasing of the deciduous species from the earlier supposed encumbrance of the allowable annual cut policy.

In my opinion, these were two policy changes that now left the ball 100% in the lap of the private sector to address deciduous utilization in B.C.'s northern interior. It was now the private sector's responsibility to put together a package that would utilize this resource, provide employment benefits for British Columbians, and still make a buck.

Unfortunately, the era immediately following this 1979 period was one of economic downturn in Canada and, as we all too painfully know, B.C. did not escape the impact. While the private sector was undoubtedly pursuing its plans for the utilization of aspen, few newsworthy public announcements were made with regard to aspen in the first few years following the 1979 symposium, the review of its results, and implementation of specific policy changes.

In fact, it is interesting to note that in the 1985-86 annual report of the B.C. Forest Service, the aspen harvest was still so insignificant that it remains grouped in with all other minor species. In fact, the harvest of this "minor species" group in the 1985-86 fiscal year amounted to only 0.6% of the provincial harvest on public and private forest lands. This insignificant percentage not only included aspen but also such species as cottonwood, alder, yellow pine, and birch. These figures provided little cause for hope that we had yet achieved great strides in the utilization of the province's deciduous resource.

During the last two to three years, however, we have witnessed a virtual revolution in the utilization of deciduous species in British Columbia. This change has primarily involved the province's Peace River area, where the greatest concentration of aspen exists. We can also foresee similar positive changes taking place in the northern interior forests lying west of the Rocky Mountains. An example of this change can be found in the Dawson Creek Forest District, where the harvested volume of deciduous timber rose from a negligible amount to approximately 15% of the total volume harvested in just one year. Recent events indicate that this percentage is destined to increase further during the next few years.

Today, a waferboard plant is in operation in Dawson Creek utilizing the aspen resource. A chemithermomechanical plant is planned for the Britannia Beach area, with its planned wood supply to be, in part, aspen chips from the province's northern interior. A pulp mill is planned for Taylor, B.C., which, like others, will be looking at the area's deciduous forests for part of its wood supply. The B.C. government is in the midst of negotiating suitable tenure arrangements that will provide for the full utilization of the area's deciduous and mixedwood forests in the northwest region of the province.

In summary, this northeastern part of British Columbia has witnessed an almost overnight revolution in the utilization of the deciduous component of its forest resource. It is fortunate that the major species affected was aspen, because this species was the major component of the northern interior's deciduous forest resource and was always considered to be the biggest utilization challenge.

Seemingly destined to be permanently scorned by logger and farmer alike as the "Cinderella weed tree", the aspen tree has found its golden slipper, and the fit has been so comfortable that some are even beginning to question whether the deciduous component of British Columbia's northern interior is sufficient to meet the demands being placed on it for future wood supplies.

REFERENCE

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Luncheon Address:

THE CHANGING PROFILE OF THE ALBERTA FOREST INDUSTRY

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It has always impressed me how personal data sound so impressive in an introduction. To those of you who were instrumental in coming up with the concept of this seminar, I offer a thank you, because I think it is a stroke of genius on behalf of the staff of the Canadian Forestry Service and the Alberta Forest Service for coming up with a very, very timely topic at this point in the history of Alberta forestry.

I thank you for the opportunity to participate in this important seminar. I understand that the Minister of Forestry, Lands and Wildlife was originally supposed to speak at this seminar, and substituting for the minister as an after-lunch speaker is a tough challenge, since most politicians have a lot of practice in speaking. Those of you who have heard the Hon. LeRoy Fjordbotten speak know that he is both entertaining and very informative and knowledgeable of the forest industry. Although he comes from a background of farming in southern Alberta, he served on the forestry caucus committee during his first terms as an MLA, and since switching portfolios with Don Sparrow of Tourism, he has quickly become very knowledgeable of the forest industry of Alberta.

Preparing comments for an after-luncheon address is always a challenge. It reminds me of the comment alleged to have been made by Zsa-Zsa Gabor's fifth husband on his wedding night: "I know what is expected of me; the challenge is to make it interesting". You can be the judge if I do not measure up, so to speak.

I suppose as a result of my current job some comments on the forest industry development occurring in Alberta might be expected, and I certainly will be making a few comments in this respect. There are, however, some other aspects that are indirectly related or in some cases directly related upon which I also would like to comment.

Last fall I was asked to speak at the Western Forestry and Conservation Association meeting in Vancouver. The panel subject was "Western forestry: sunrise or sunset". I had a great deal of difficulty focusing on that particular subject, and quite frankly it did not occur to me until recently—in fact, not until I was preparing these comments—why I had some difficulty. It is because, I think, to a large degree Alberta's day in the sun, so to speak, has yet to dawn. That is not to deny the interesting history and development of our sawmill industry, which has been around for more than 70 years, nor to deny the great impact in contribution that bleached kraft pulp mills (Champion as well as Procter and Gamble) have made to Alberta or the plywood industry of Zeidler and more recently Canfor and CFI. The point that I am making now is that up to a couple of years ago, we were harvesting only about 30% of our allowable annual cut. Our day, so to speak, had yet to come.

But we are now on the verge of a dramatic increase in utilization of our timber resource in Alberta. In the past 3-4 years, sawmill production has jumped from 1 billion to 1.4 billion sq. ft. Oriented strand board, a new product, went from no production to 650 million ft. (3/8-in. equivalent). Medium-density fiberboard, a new product, is now at 50 million sq. ft. (3/4-in. equivalent). We know that in the next 3-4 years pulp and paper production will rise dramatically: softwood bleached kraft pulp from 500 000 to 820 000 tonnes; hardwood bleached kraft from less than 30 000 tonnes a few years ago to 300 000 tonnes; chemithermomechanical pulp (CTMP) from no production to 200 000 tonnes; newsprint from no production to 220 000 tonnes.

I believe in the next 3-4 years lumber will increase by another 250-300 million board feet (bd. ft.). Now, with the exception of the lumber figure, the above figures do not include any speculation; they are based on announced projects. I am confident that one or more additional major pulp and paper projects will be announced before the end of the year. I do not think I should speculate on the specifics, partly because the type of mills that will be approved will obviously influence the projected increase of the specific product, whether it will be chemical pulp, mechanical pulp, paper, or some panelboard product. I am confident that the value of sales of our forest products, which now total about $1 billion a year, will exceed $3 billion by the year 2000.

I titled my remarks, "The changing profile of the Alberta forest industry". There is another change occurring in the industry that I find particularly interesting, and that is marketing. Historically, Alberta's forest products have mainly gone south to the United States, while some of the production has also been absorbed into the Canadian market and only an incidental volume went offshore. This situation has been undergoing a significant shift. Lumber is now being exported to Japan and the United Kingdom. Although I could not get any specific figures, my best guess is that we will exceed 50 million bd. ft. in this calendar year. I realize that this is only a minor component of the total volume that we are producing in Alberta or of what is going to the United States. It represents a trend that I predict will continue and will dramatically increase in the next 5–10 years. The 2 ×4 market in Japan has been making great inroads in the traditional post and beam construction in that country.

There are now a number of Alberta companies (and outside companies as well) that are studying Alberta as a base for not only 2 ×4s but also specialty wood or metric mills for offshore markets. There is particularly strong interest in Alberta white spruce, and I believe that before the end of the year there will be projects involving specialty mills or mills that are devoted primarily or specifically to offshore markets.

Medium-density fiberboard (MDF) is another product that is receiving great acceptance in the Pacific Rim. I recently came back from visiting three countries in northeast Asia, and a number of company representatives came to me complaining that they were unable to get all the MDF they wanted from Blue Ridge Lumber. I do not know what percentage of Blue Ridge's production is going offshore, but I do know that the market in the Orient is going to grow in the future. Oriented strand board is less well-known, and the constant high humidity in both southeast and northeast Asia is a concern that has to be resolved because of the question of dimensional stability in the presence of high humidity. This must be resolved, I think, before significant market inroads are made there.

Plywood is readily accepted and well-known but receives very tough competition from southeast Asia, where wood and labor are both very cheap and low transportation costs are a real asset.

With respect to pulp, Daishowa has indicated that 50–70% of its production of hardwood bleached kraft pulp would be going to Japan and other Asian countries. I am certain that Millar Western's CTMP will receive ready acceptance in this market and will be an important and growing market for Alberta's CTMP, generally. The Alberta Newsprint Company will, I believe, direct some of its production into this market as well. I predict that in less than a decade Pacific Rim companies will grow from virtually 0% of our market (or at least a negligible percentage) to about 30%.

There are many people who have expressed surprise at the rapid expansion of our forest industry. Having worked in Alberta for 10 years I felt the same frustration that I know some of the other senior staff and our Deputy Minister Fred McDougall have felt over the fact that a major breakthrough in forest industry development seemed to always to elude us.

The major breakthrough, of course, was the utilization of hardwood, which for many years represented 45% of our allowable cut and less than 5% of the actual harvest. The oriented strand board mills of the Pelican and Weldwood companies started the process, but the dramatic breakthrough has been the decision of Daishowa to use 1.5 million m^3 per year for hardwood pulp.

What are the factors influencing the sudden interest in pulp and paper in Alberta? I believe there are a number of reasons. First and foremost, the economic strength and the profitability of the forest industry are certainly important. Prices for pulp and paper are at record highs, and the tight supplies and high prices are causing both North American and offshore companies to look for new green-field opportunities.

I believe the strong signal sent to the private sector by the Premier and the Government of Alberta with this special program that I have the privilege to be heading (forest industry development) has been an important factor as well. Also, our promotional and advertising program has been effective in attracting both North American and offshore investment. I think, however, there are even more important factors. We had something to offer: an abundant forest resource; lowest wood costs in North America; low energy and electrical costs; excellent, stable and productive labor; a secure forest tenure; competitive corporate taxes; and a very sophisticated and well-developed fabrication and contracting industry. The highly competitive and deregulated transportation industry could not have come at a better time for us.

One question that seems to be asked more and more frequently these days, especially by the general public, is whether our resources can stand such expansion of the industry. I refer back to a point that I made at the very beginning, that up to a few years ago Alberta had 18 million m^3 of allowable cut surplus to our needs and to the industry, enough for 10 bleached kraft pulp mills such as Daishowa's or 30 Millar Western CTMP mills. I realize straight-line projections such as that can be misleading for obvious reasons, but I use them to indicate the magnitude of the surplus forest resource in Alberta.

Another comparison that I found might be useful is that the forest resources of the four Atlantic provinces very roughly equal those of Alberta. The Atlantic region has 17 or 18 operating pulp and paper mills, and until Millar Western gets its mill going this summer we have 2.

Before concluding, there is an aspect of our changing industry that gives me a very good feeling. Our industry is technologically current and modern. Alberta was the first province in Canada with an oriented strand board plant, and it was the first province in Canada with a medium-density fiberboard plant. The Millar Western CTMP mill will be the first one in western Canada; we were just beat out by the Tembec mill in Quebec as the first one in Canada, as the first green-field CTMP mill.

We will probably have the first newsprint plant in Canada using significant volumes of aspen in the furnish. The Daishowa plant in Peace River will be the first green-field bleached kraft pulp plant to install oxygen delignification and will be unique in the use of huge volumes of aspen and black poplar for the hardwood bleached kraft pulp.

To a very substantial degree our industry is modern and up-to-date. Even our sawmill industry, which is more than 50 years old, is improving and modernizing with such technologies as scanners, optimizers, and automated log-handling in the log yards. Canfor announced just a few weeks ago a $35 million modernization of its sawmill program, and I know I could go on with many other companies that have either committed or are about to commit themselves to upgrading their sawmills.

This seminar indeed is timely. For the first time in our history we have a good chance to address in a meaningful way the management of mixedwood stands, not as a theoretical situation but as a real situation in which the forest industry has the opportunity to use mixedwood. All those associated with the industry will benefit, I believe, from this important seminar.

MANAGING WHITE SPRUCE IN ALBERTA'S MIXEDWOOD FOREST: THE DILEMMA

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ABSTRACT

The paradigm under which we have been managing white spruce (*Picea glauca* (Moench) Voss) in the mixedwood forest zone of Alberta—a reliance on extensive management systems with the objective of replicating wild forest yields and species—is being rendered inadequate by the competitive pressures of grass and brush and hares (*Lupus americanus*). Over the past two decades, alternative systems for regenerating white spruce have been explored and a broader array of treatment options developed. Application of this knowledge—the recognition of the problem, the understanding of the solution—is forcing a paradigm shift in how this mixedwood forest is being managed. In Alberta, we are moving toward the adoption of more-intensive, front-end regeneration treatments; we are better defining our management objectives, at least in terms of primary species of interest, and we are moving toward an optimizing rather than a minimizing outlook on regeneration expenditures. These changes bode well for the growth of new spruce plantations and for the contribution that white spruce will make to an increasingly dynamic forest industry in Alberta.

INTRODUCTION

In the summer of 1986, Alberta and British Columbia cohosted the annual meeting of IUFRO (International Union of Forest Research Organizations) Working Group S1.05.12, Northern Forest Silviculture and Management. There was good international representation at this meeting, including about 20 representatives from Sweden who were in Canada primarily to trace the roots of their most important commercial tree species, western Canada's lodgepole pine. I recall a comment by one Swede in the bush south of Grande Prairie. "These are excellent sites," he said, "and I'm glad you have them, for we certainly wouldn't know how to regenerate them." This is a cogent comment. Probably unbeknown to the Swedish forester, he succinctly described the issue, the opportunity, and the dilemma that we are now wrestling with: how do we, how could we, how should we manage white spruce (*Picea glauca* (Moench) Voss) in the mixedwood zone of Alberta?

ALBERTA'S BOREAL MIXEDWOOD FOREST ZONE

What does the mixedwood zone of Alberta look like? When described as an ecoregion on the basis of distinct regional climate as expressed by vegetation sequences (Strong and Leggat 1981) (Fig. 1), it is both large and diverse. The boreal mixedwood region encompasses 286 000 km² and is the largest ecoregion in Alberta, occupying 43.2% of the land area. The region is made up primarily of a deciduous forest of trembling aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), with white spruce and balsam fir (*Abies balsamea*) the potential climax species. Corns and Annas (1986) have identified 15 associations in Alberta's mixedwood zone, three of which are discussed below.

The **white spruce/feather moss** association (35% *Picea glauca*, 16% *Populus tremuloides*, 10% *Abies balsamea*) generally occupies the middle area of the landscape cross section. The soils are typically Gleyed Grey Luvisols, and are generally moderate in moisture and nutrient regimes. On some sites, excess soil moisture is a limitation to reforestation.

The **white spruce/mooseberry/wild sarsaparilla** association (aspen facies—47% *Populus tremuloides*, 11% *Picea glauca*) also occupies the middle area of the boreal mixedwood forest landscape. The soils are typically Orthic Grey Luvisols. The landform is morainal or lacustrine; soils are generally imperfectly to well-drained. Moisture regime is modal in status, and the nutrient regime ranges from moderate to rich. Excess soil moisture on some sites limits reforestation.

The **white spruce/red osier dogwood/wild sarsaparilla** association (38% *Picea glauca*) typically has soils that are generally moderately well to poorly drained Orthic Gleysols. The landform is fluvial but could be morainal and lacustrine, the soil moisture regime is modal, and nutrient levels are generally high. The sites are generally productive but, again, excess soil moisture limits reforestation.

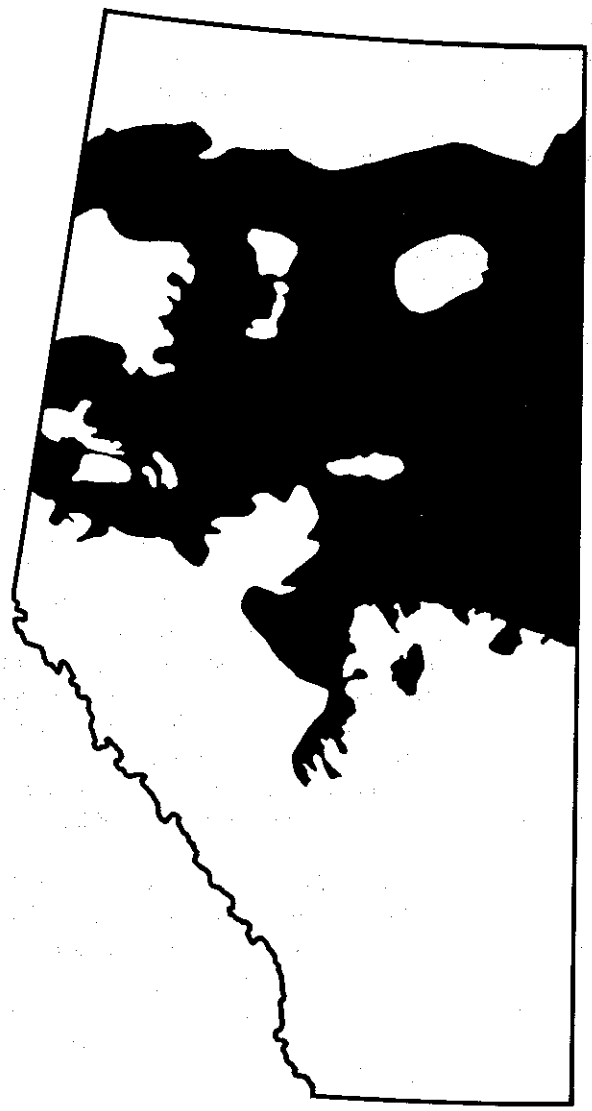

Figure 1. The boreal mixedwood ecoregion in Alberta.

Wildfire and wet soils on some sites have had and continue to exert a very significant influence on the type of forest found in Alberta's mixedwood zone. About 75% of Alberta's forest land has been burnt over in the past 50 years, creating the young successional mixedwood forest described above. This young fire-origin forest is generally dense, with many small-diameter trees and growing on average at around 1.67 m^3/ha per year—numbers that are probably representative of rates found for the unmanaged forests across the northern boreal forests of the world. Given their soil properties and nutrient status, these forests are capable of producing much higher yields under management, probably in the order of a sixfold improvement as suggested by Boyd (1985).

Next to fire, impeded drainage is perhaps the second most distinctive feature of the mixedwood zone in Alberta. Alberta's lack of significant relief away from the Rocky Mountains was established during the Paleozoic and Mesozoic eras, from 70 to 600 million years ago, when the climate was tropical and the land was periodically submerged under seas. Within the last one million years—recent geological history—Alberta's climate changed to arctic conditions with four different ice-sheet periods. The advance and retreat of this ice eliminated plant and animal life from Alberta and deposited the glacial till that forms the parent material of many of today's soils. The landforms created include about 13 million hectares of peatland in Alberta (Tarnocai 1984); I estimate that about 60% of the peatland is located in the boreal mixedwood zone.

The mixedwood zone of Alberta now supports a young, dense forest of aspen, with residual pockets of climax white spruce on areas with no recent fire history. Soils are generally suitable for tree growth, being workable, nutrient-rich, with adequate moisture, and under no substantial agricultural drought. The wood-growing potential of this forest is high; however, impeded drainage does limit tree growth and summer access in some instances, and reinforces the need for quite specialized regeneration systems.

STATUS OF SPRUCE REGENERATION IN ALBERTA

The objective of Alberta's reforestation effort is to replicate the wild forest yields that are harvested, yields that range from 50 to 190 m^3/ha grown in about 60–180 years. On the expectation that this yield, which nature produced unaided, should be fairly easy to duplicate after logging as long as a conifer seed source or conifer seedlings are present, the regeneration standards adopted with the Alberta quota policy in 1966 focused on stocking. These standards are embodied in Sections 123–145 of the Timber Management Regulations (Alberta regulation 60/73). These require that a block must be treated within 2 years of harvest and surveyed before the end of the 7th year so that these areas would be checked off at Year 10, evenly stocked at an 80% level with a minimum of 800 3-year-old crop trees per hectare. It was believed that these modest standards would meet the Alberta Forest Service's guiding principle of sustained yield management.

Reforestation practices in Alberta are generally extensive in nature. For instance, in the 4 years before 1979, the Alberta Forest Service (AFS) and quota operators planted 8.1% of the area harvested, scarified and planted another 8.4%, scarified and seeded 30%, scarified and left for natural seeding about 22%, and left 31% of the areas with no prescribed treatment, expecting sufficient natural regeneration (Fig. 2). These practices became a little more intensive after 1979, with planting through 1983 increasing to 20% of the area harvested; in the same period, the area scarified and seeded declined by 30% (Fig. 2).

Given the standards that the AFS thought would be necessary to deliver the type of forest harvested, these practices have been resoundingly successful. Historically, 96% of the area harvested has met or exceeded designated standards. These results are the envy of every province in Canada. Considerable dollar investments, reasonable technology, good growing sites, and a pattern of cutting have generally left Alberta foresters with abundant natural seeding, helping them to be very successful. A field survey was initiated in 1984 to review the performance of the older checked-off blocks. A 5% intensity survey was conducted, involving 318 cut blocks randomly selected across the province as being representative of areas harvested from 1967 to 1974. All these areas, about 100 000 ha in total, had been checked off as being satisfactorily regenerated for at least 5 years prior to the survey. The survey was conducted using a reduced-intensity formal Alberta Regeneration Survey. Information was collected on stocking, density, height, and competition[1].

To summarize the survey results, the following points are noted:

1) In terms of stocking, about 30% of the blocks were below current standards;

2) Total densities were high—on the spruce moist sites there were on average 3642 acceptable conifer, 2976 conditional species, and 1481 aspen seedlings per hectare;

3) The species composition of this forest had changed—about 50% had reverted to hardwood, 16% were mixedwood, and 33% were conifer;

4) Competition from grass and shrubs was intense, with 33% of the crop trees experiencing competition from grass and 42% from shrubs;

5) Growth on the crop trees was reasonable, with minimal damage from other factors; and

6) The difference between average crop tree age and block age was diverging over time; a 10-year-old climax forest seemed to have been created.

The clear message from this work is that the regenerated blocks are probably not replicating wild forest yields for the reasons mentioned; regeneration standards need revision if sustained yield objectives are to be realized. It is time that a free-to-grow objective was considered in Alberta, and cleaning and tending seem necessary functions in the regenerated forest.

Grass, brush, hardwoods, and hares are the primary elements providing the *coups de grâce* to regenerated spruce in the forests of Alberta. These are not unsolvable problems. Double disking has proved to be an effective site preparation tool, controlling hardwood ingress while providing soil tillage. Tillage on the heavier-textured clay soils is very beneficial to early seedling growth. Plowing, such as with the Finnish Marttiini plow, has also provided good regeneration results. Selective use of herbicides has proved to be effective in controlling hardwood ingress, stimulating rapid early growth on planted spruce.

Except for toxicants, which are not used in Alberta, no effective hare control technique has yet been found (Radvanyi 1987), through two avenues are being explored. Evaluation of a range of control options from repellents to trapping and fencing is ongoing, but there is recognition that if all else fails, our focus must change to one of coexistence. In terms of this latter strategy, a combination of intensive regeneration, cleaning, and tending to promote fast, early growth and an understanding of the dynamics of the hare population and the use of repellents and other control measures at the appropriate time should enable us to see spruce through the hare "blooms", given the hare cycles and spruce seedling growth rates projected for Alberta (Fig. 3).

[1] This work will be published by Bamsey and Sunderland of the Alberta Forest Service at a future date.

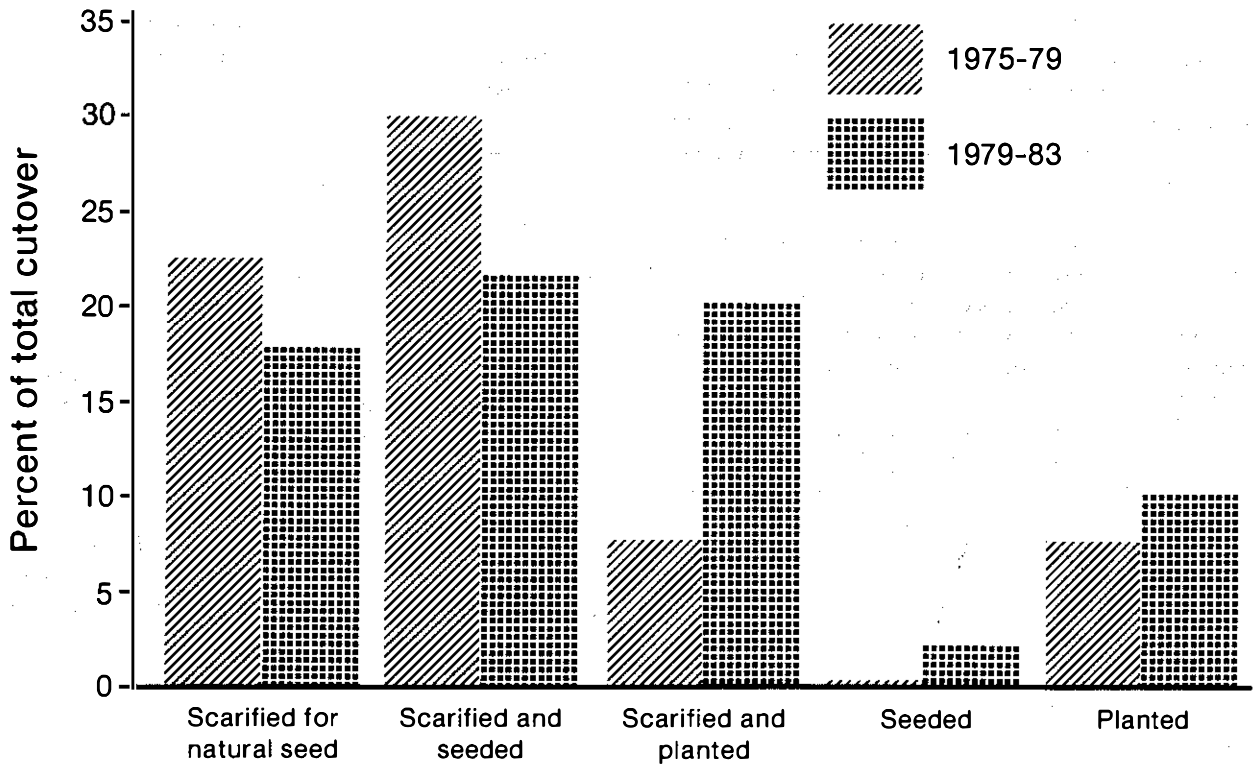

Figure 2. Regeneration treatments adopted in Alberta in the late 1970s and early 1980s.

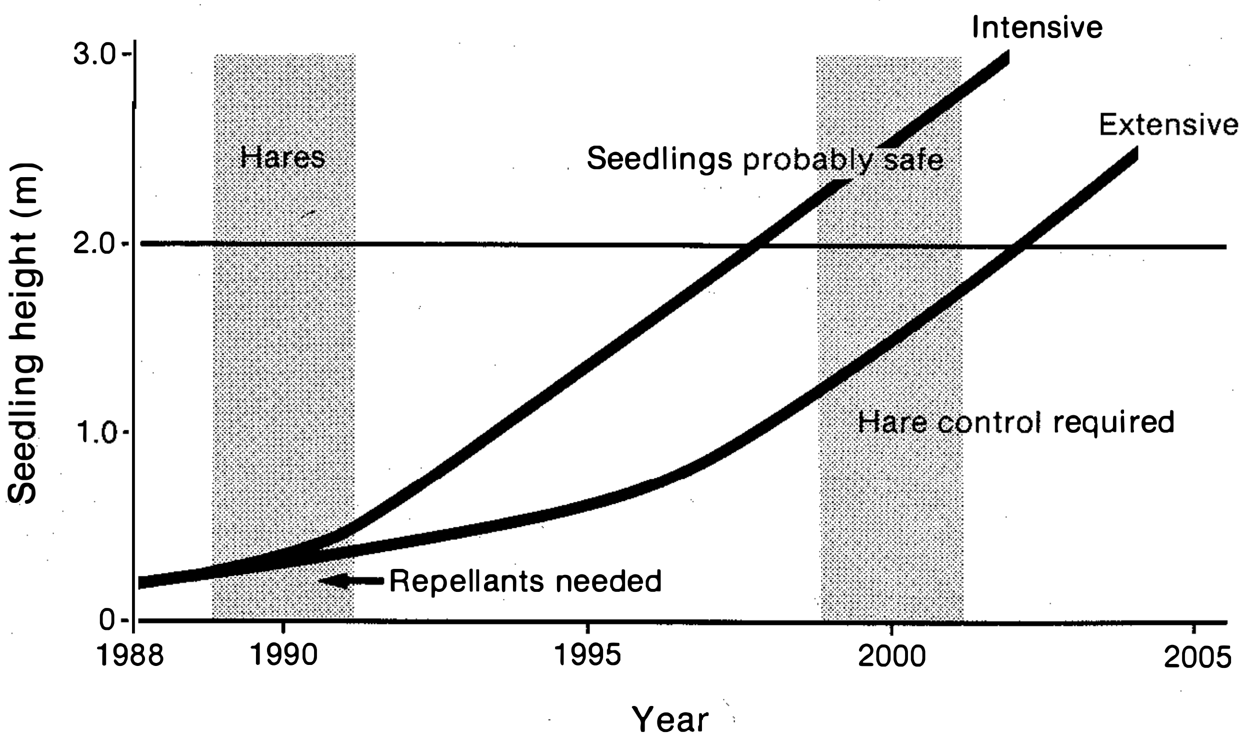

Figure 3. Growing spruce to coexist with the hare cycles in Alberta: the need for intensive regeneration treatments.

The AFS is confident that given an intensity of effort and tenacity of commitment, spruce can be regenerated in the boreal mixedwood of Alberta. The economic and financial ramifications of these activities are thought to be positive, and terms of reference for such a program are now being explored.

THE PARADIGM SHIFT

The paradigm under which we have been managing this forest—a reliance on extensive management systems with the objective of replicating wild forest yields and species—is being defeated by the competitive pressures of grass and brush associated with high sites. Grass is often lethal to young regenerated tree seedlings, and brush slows growth to the extent that these seedlings are lucky to grow beyond the browse limit of hares. Ultimately, it is the hare who has supplied the *coup de grâce* to many of our newly regenerated plantations; it is the hare who limits the practicality of mixedwood management systems that plan for spruce development in an understory position. Understanding the success of our past regeneration efforts creates a difficult conundrum; we know that extensive regeneration systems will not give us conifer survival and growth sufficient to replicate the wild forest yields that are planned. This understanding provides both the pressure and momentum to change (Fig. 4).

The direction of change (also considered in Fig. 4) develops from the belief that we can grow spruce in the mixedwood forest if we so choose. Over the past two decades, alternative systems for regenerating white spruce have been explored and much has been learned. We know how to regenerate even our best sites, keeping the competitive pressure to a minimum using both mechanical and chemical treatments. We are learning about regeneration systems that promote substantial first-year growth in planted spruce seedlings, doing away with "planting shock" and expectations of slow early growth in spruce. We know the value of cleaning and tending to keep established spruce growing. We believe we can coexist with the periodic explosions in hare populations by better understanding the population dynamics of the hare, the types of plantations that may be at risk, and the control options that are available to us.

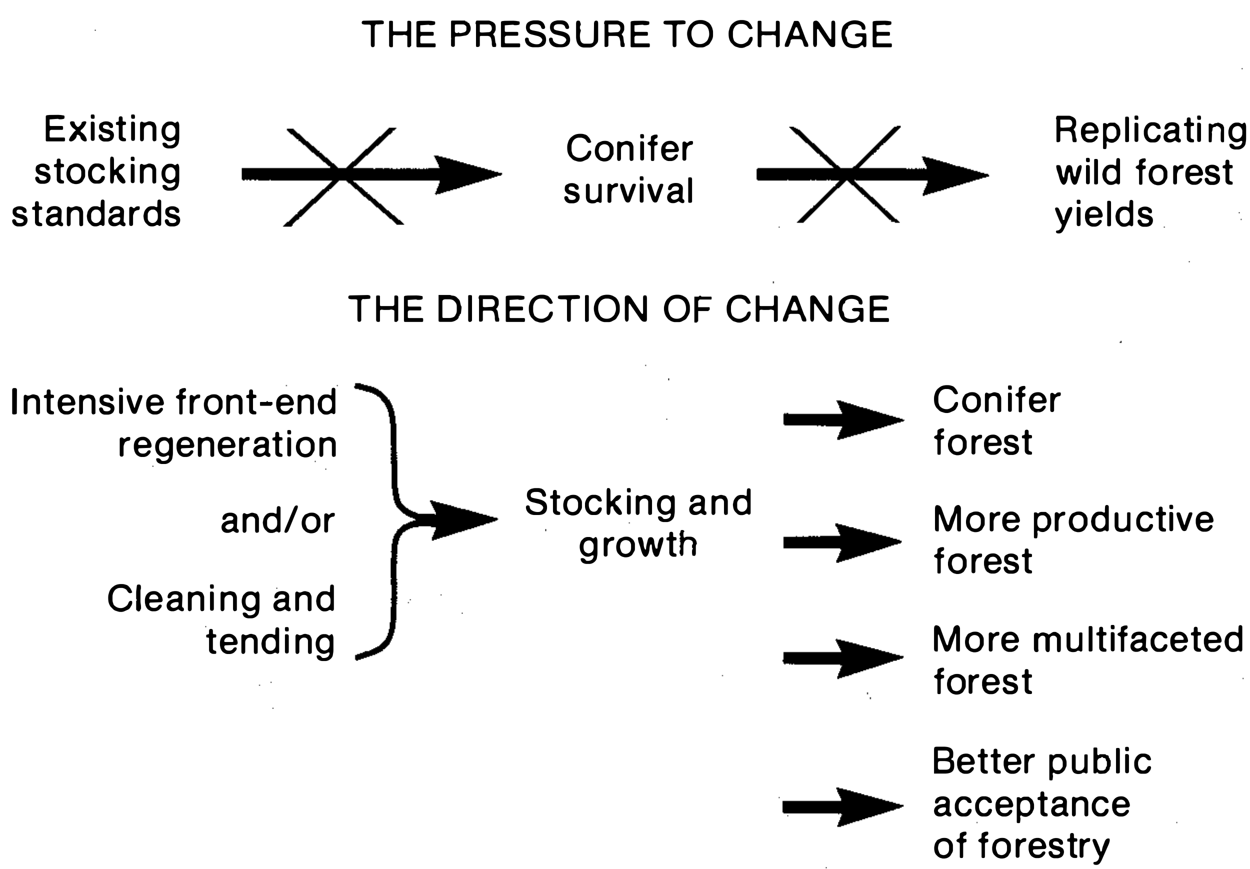

Figure 4. Understanding the paradigm shift: the pressure and direction of change.

We know how to regenerate spruce with a high probability of success; however, recognize that to do so will force a paradigm shift in how we manage this forest. The application of more-intensive regeneration systems to those areas designated for conifer production will necessitate the expenditure of more front-end dollars in establishment. These expenditures will both secure the success of the regeneration itself and, almost as a by-product, will produce better, faster-growing stands than would be obtained naturally. The practice of regenerating spruce ceases to be a minimizing exercise to be accomplished as cheaply as possible. It becomes an investment decision, one more oriented toward getting the most from the dollars expended in regeneration.

In the boreal mixedwood of Alberta, the silviculture requirements of spruce are driving the change in how we manage this forest. Major paradigm shifts are not easy to implement and take time to get acclimatized, culturally; this shift will be no exception. In terms of regenerating spruce we see little option but to intensify silvicultural practice at this time. In a managerial sense, there is really not much of an option—clearly, the spruce forest is an essential contributor to basic principles of sustained yield and multiple use values.

The mixedwood forest is unlikely to regenerate itself successfully with an extensive "we'll take what comes back" statement of objectives. The reed grass field of northern Alberta is being recognized as an increasingly familiar result of this type of management strategy. There are options, however, that do not exclude a mixed species forest. Managing for either spruce or aspen is likely to result in some form of mixedwood product, whether we want it or not, for aspen and spruce are fairly ubiquitous to this zone. There are many examples in the wild of spruce ingressing as an understory to the aspen pioneer crop; there are even more examples of aspen taking over areas that were both logged as conifer and regenerated to conifer. Regardless of whether the management objective is spruce or aspen, one may expect to see a substantial presence of both species in the managed forest, and few would argue with the acceptibility of this.

Spruce, by way of its contribution to timber, wildlife, and aesthetics, is deemed to be a necessary ingredient to our forest cover. It will take some effort to maintain its presence; however, in doing so by staying the course and growing spruce, better forest management and a more dynamic forest industry will be the result.

CONCLUSIONS

The wood growing potential of Alberta's mixedwood forest zone is high. Soils and climates are favorable, and the sites are generally nutrient-rich with adequate moisture. This potential is currently not being realized because of a general reliance on extensive regeneration systems that result in few areas growing free of the nemeses of the new forest: grass, brush, hardwood, and hares.

More-intensive regeneration systems, including the use of double disking and plowing techniques and the selective use of herbicides, have worked well in Alberta. The paradigm shift to these more intensive techniques results from a better definition of the management objective. The decision to grow either conifer or hardwood under more-intensive culture will not remove the traditional mixedwood scene of aspen and spruce from the forest mosaic—each is fairly ubiquitous under our present harvesting patterns. The prevailing laissez faire attitude to mixedwood management—regenerate extensively and live with what you get—will effectively, over time, cause the harvested conifer forest to be replaced by stands of hardwood and brush fields of reed grass. If this scenario were to continue, the nature of the forest would change, making it less ideal for meeting either sustained yield or multiple-use objectives.

The regenerated conifer forest under more intensive culture may be six times as productive as the forest it replaced, and the thermal cover it will ultimately provide to the large browsing animals is necessary. The presence and contribution that white spruce make to the forest estate of the mixedwood zone of Alberta will not diminish. The recognition of its value, the understanding of its culture, and the commitment to deliver will combine to increase the presence and value of this important crop species.

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ALASKA'S INTERIOR FOREST

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ABSTRACT

Alaska's northern forest has a potential for development that currently is being ignored. The forest resources of the region compare favorably with similar forests in Minnesota, Michigan, Canada, and Scandinavia. Current utilization is confined to white spruce, because hardwood species have little use beyond fuelwood. Lack of infrastructure along with limited research in all aspects of intensive forest management, plus the high cost of doing business in this remote state, have slowed development. Utilization of a high percentage of low-grade fiber demands state of the art technology for success. Commitment to develop this wood resource by government is limited. Intensive management of these forests could assist the state in maintaining its standard of living, which currently depends heavily on declining oil revenues.

INTRODUCTION

The area of Alaska is approximately one-fifth the area of the continental United States (Fig. 1). The latitudinal position of the state is similar to that of Scandinavia (Fig. 2).

Alaska has 48 million ha of forest land. This represents 16% of the forest land in the United States. Of this, 11.4 million ha are considered commercial forest land, that is, capable of producing at least 1.4 m^3 of wood per hectare per year. Interior Alaska, located between the Brooks Range and the Kenai–Chugach Mountains (Fig. 3), has 8.9 million ha of commercial forest land, which is more than three-quarters of the commercial timberland in the state. The majority of the timber volume and industry, however, are in southeast Alaska, where there are approximately 2.4 million ha of commercial forest.

The net volume of growing stock (gross volume less deductions for defect) on commercial forest land is approximately 1400 million m^3. About 70% of the net growing stock is found in coastal forests, with the remainder found in interior forests. In the coastal forests, 94% of the volume is found in trees greater than 27.9 cm in diameter; in contrast, 58% of the interior's growing stock is found in trees 12.7–27.9 cm in diameter.

Although most of Alaska's forest land is in the interior, most of the sawtimber is in the southeast. There, the coastal forests average nearly 990 m^3 of sawtimber per hectare; interior forests average only 42 m^3/ha. It should be pointed out, however, that within the vast interior there are numerous sawtimber stands with volumes greater than 300 m^3/ha.

In the southeastern coastal forest, western hemlock (*Tsuga heterophylla*) and Sitka spruce (*Picea sitchensis*) predominate, with lesser amounts of mountain hemlock (*Tsuga mertensiana*), western red cedar (*Thuja plicata*), and Alaska yellow cedar (*Chamaecyparis nootkatensis*). Alder (*Alnus* spp.) are plentiful along stream and beach fringes and where the soil has been disturbed. Black cottonwood (*Populus trichocarpa*) grows on the flood-plains of the rivers that drain the coastal mountains. Small quantities of subalpine fir (*Abies lasiocarpa*), Pacific silver fir (*Abies amabilis*), and lodgepole pine (*Pinus contorta*) are scattered between tidewater and high elevation tundra.

White spruce (*Picea glauca*) is currently the principal commercial species in the interior forests. Paper birch (*Betula papyrifera*), quaking or trembling aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*) accompany white spruce or occur in pure stands on the warmer, well-drained sites. On the cooler, wetter sites,

Figure 1. Comparative sizes of Alaska and the Lower 48. (Source: Hartman and Johnson 1978.)

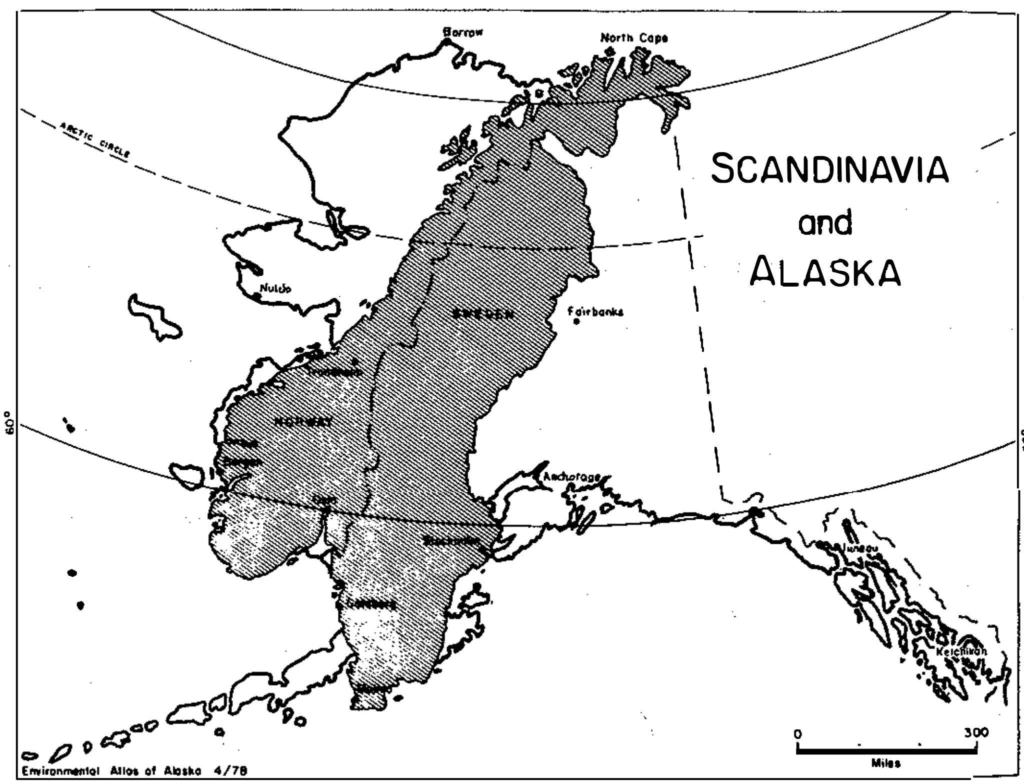

Figure 2. Latitudinal positions of Scandinavia and Alaska. (Source: Hartman and Johnson 1978.)

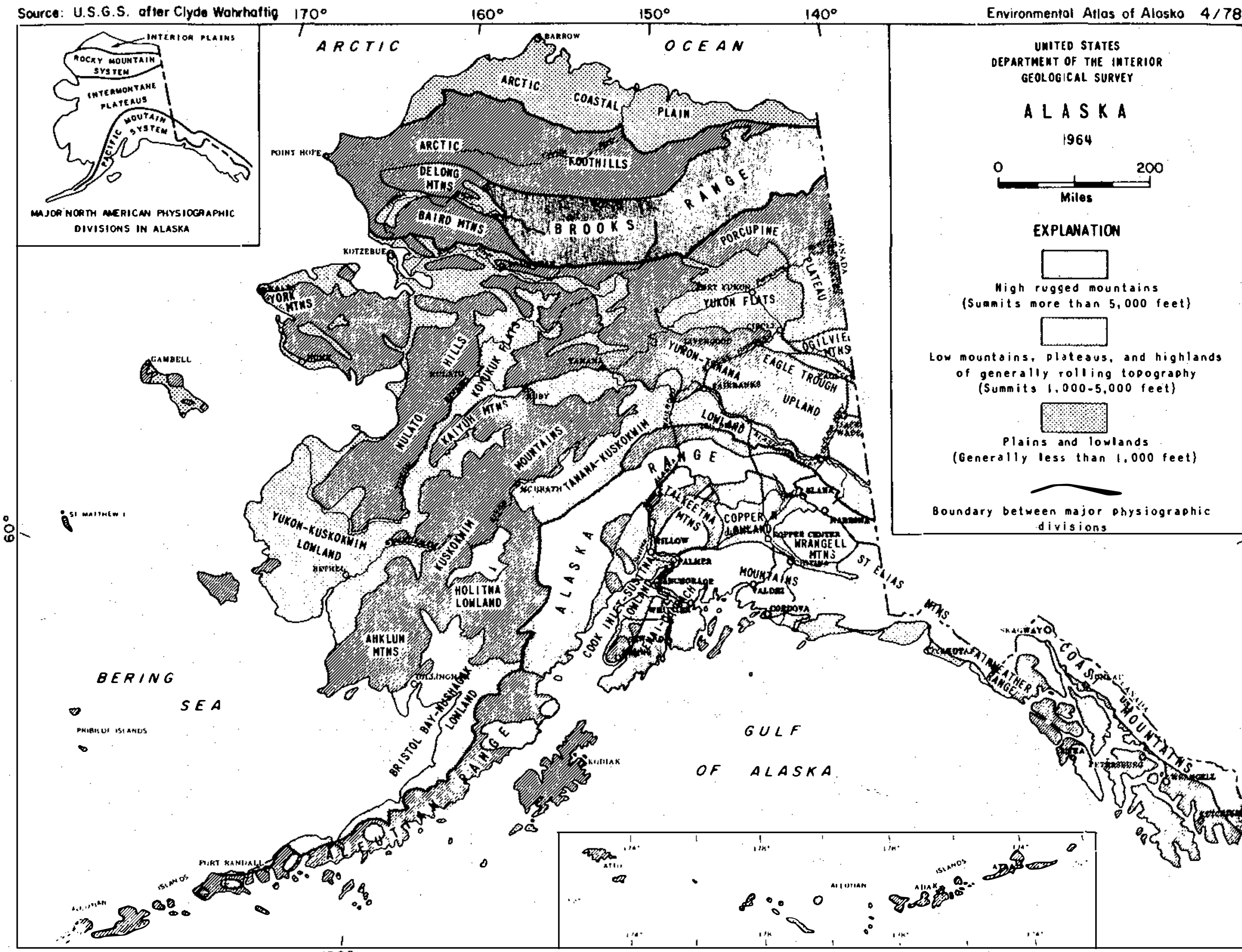

Figure 3. Physiographic provinces of Alaska. (Source: Hartman and Johnson 1978.)

black spruce (*Picea mariana*) and tamarack (*Larix laricina*) occur. Willow (*Salix* spp.) are abundant and are an important food source for wildlife.

NORTHERN FOREST RESOURCE

The northern forest of Alaska, also referred to as the boreal forest or taiga, has fewer species than the Canadian northern forest (Table 1). Alaskan forests are generally less continuous than those of much of Canada. In Alaska the best timber stands are commonly confined to valley bottoms and south-facing slopes with tundra, muskeg, or scrub separating timbered areas. Productivity of the Alaskan interior forests is comparable to the northern forests of Canada (Table 2).

Forest ownership in Alaska is complex. At the federal level, land is managed by the United States departments of Agriculture (Forest Service), Defense (Air Force and Army), and Interior (Bureau of Land Management, Bureau of Indian Affairs, Fish and Wildlife Service, and National Park Service). At the state level, forest land is managed by the departments of Natural Resources and Fish and Game, and the University of Alaska. Furthermore, each borough (similar to a county) controls areas of forest land within its boundary. Major private holders of forest land are native regional corporations and village corporations as well as individual natives. Each has different management goals and goals vary within each agency or group.

HISTORICAL UTILIZATION

Alaska's original inhabitants recognized the value of the forest resource as they fought to survive in their harsh environment. Willow and spruce were used for fish traps, tools, bowls, sleds, snowshoes, and canoes. Wood and salmon formed the material basis of the culture of the early Alaskan peoples.

White man came to the territory searching for furs and minerals and soon began to utilize the wood source for house logs, fuelwood, and mine timbers. The coastal forests almost immediately experienced industrial growth directly related to the utilization of the spruce and hemlock forests. Russians were the first to harvest the coastal forests, and they established sawmills and shipyards prior to 1807. The purchase of the territory by the United States slowed the development of the forest industry with federal policies and regulations that allowed no harvest of timber from public domain lands. With the establishment of the federal forest reserves at the beginning of the 20th century and the arrival of the U.S. Forest Service with a high priority to offer timber sales, industry began its growth in Alaska.

Most early logging in the interior forests of Alaska supported the mining and fishing industries. Wood was used to fuel steam locomotives, steam driven engines for power plants, and sternwheelers for transportation on the river systems; it was also used as rough lumber or house logs for community development. Then, as today, residents of the interior forests imported most of their lumber and building materials.

CURRENT UTILIZATION

Alaska's interior forest industry is embryonic in nature, with many small, marginal operators making a living from the resource. The mainstay of the industry is white spruce; there is only limited development of the hardwood resource beyond low-value fuelwood. Nearly every logging and sawmill operation uses older equipment purchased outside of Alaska that usually is not well-adapted to the job at hand. In general, sawmill operators produce semifinished or rough-cut, green lumber. The lumber if dried, is air-dried. The most profitable product is house logs followed by timbers, rough-cut lumber, and finished lumber.

Most Alaskan operators find it difficult to compete with Canadian imports of kiln-dried, dressed, and graded dimension lumber that is produced in greater quantities by technically superior mills in B.C. It has been less expensive for some mill operators in interior Alaska to import round logs from Watson Lake, Yukon, than to buy stumpage and harvest logs from local forests. Few of the interior mills have made the additional investment necessary to produce graded lumber and capture a share of the import market; however, such important substitution is seen by many analysts to be the most economically feasible use of the interior forest resource.

Due to today's limited use of Alaska's extensive hardwood resource, there are many opportunities to produce value added products. Current technology can be used to establish sophisticated operations that utilize this basically untouched, low-grade fiber supply.

IMPEDIMENTS TO MANAGEMENT AND UTILIZATION

Even with Alaska's effort to diversify the economy, the state government has shown little commitment to

Table 1. Species characteristic of the northern forest, by political unit[a]

	Alaska	Yukon	Northwest Territories	B.C.	Alberta	Sask.	Manitoba	Ontario	Quebec	Nfld.
Abies balsamea					*	*	*	*	*	*
Abies lasiocarpa		*	*	*	*					
Larix laricina	*	*	*	*	*	*	*	*	*	*
Picea glauca	*	*	*	*	*	*	*	*	*	*
Picea mariana	*	*	*	*	*	*	*	*	*	*
Pinus banksiana			*		*	*	*	*	*	
Pinus contorta		*	*	*	*					
Thuja occidentalis							*	*	*	
Betula papyrifera	*	*	*	*	*	*	*	*	*	*
Populus balsamifera	*	*	*	*	*	*	*	*	*	*
Populus tremuloides	*	*	*	*	*	*	*	*	*	*

a Asterisk indicates species appears in that area.

Table 2. Forest productivity by political unit[a]

	Total land and water ('000 ha)	Commercial forest ('000 ha)	Mean annual increment (m^3/ha/yr)	Merchantable timber ('000 000 m^3)
Alaska	151 942	11 400		1 400
Interior		8 900	1.45[b]	420
Yukon	53 656	10 957		
Northwest Territories	338 113	8 804		
B.C.	94 789	54 590	2.03	7 610
Alberta	66 146	24 343	1.75	1 687
Saskatchewan	65 219	8 756	0.99	482
Manitoba	65 036	15 326	1.54	361
Ontario	106 904	46 749	1.26	3 156
Quebec	154 134	49 329	1.26	3 694
Newfoundland	40 469	8 903	1.42	113[c]

a Canadian data from Manning and Grinnell (1971) and Reed and Associates (1978).
b Best sites for white spruce in Fairbanks area.
c Does not appear to include Labrador.

developing its timber resource. It has invested few dollars in management of its forest lands compared to what it has plowed into agriculture, fishing, and tourism and recreation.

After years of planning there still exists no clear direction from the state government as to where, when, and what kinds of forest development will be pursued. Written documents are nonexistent on the subject, even though there has been much discussion. This is due to many reasons, but the most overriding seems to be politics. The government does not stand up well to criticism by organized, vociferous, special interest groups that for the most part see Alaska as their last wilderness stronghold. Add to this the fact that many immigrants to Alaska came to get away from the growing crowds in the lower 48 states and you end up with an attitude of "the last man in, slam the door behind you!"

The state has undertaken several programs to assist the forest industry. The governor called a task force in late 1984 to conduct a comprehensive evaluation of the forest industry situation. The task force made a large number of recommendations, most of which have not been addressed, though the state has established an Office of Forest Products within the Department of Commerce and Economic Development. Results of trade missions between Alaska and Pacific Rim nations are difficult to measure. Attempts to establish new state forests and bring increased forest management to interior lands continue to be a low legislative priority.

There are certainly other problems in developing a forest industry on the "last frontier", the most glaring of which is the lack of infrastructure. Access to the resource across a mottled muskeg-forest terrain is limited. Roads and associated bridges are infrequent, and the existing, accessed rail belt covers only a small portion of the interior. The cost of doing business and trying to extract a profit out of the high percentage of low-grade wood challenges even the most efficient logging and milling operations. Costs of doing business, in general, appear to be higher than in most parts of the world. Meeting the ever-growing list of required notices, permits, public hearings, and land use plans tends to further dull enthusiasm for the rewards of investment that can be visualized in the future.

Another consideration is the state's Forest Resources and Practices Act, which demands the regeneration of the harvested forest. Regeneration of white spruce, the species the local industry depends on almost exclusively, could prove to be very expensive due to the lack of adequately spaced seed years (one good year in seven) and the severe competition from bluejoint grass (*Calamagrostis canadensis*). Existing timber sale contracts depend on natural regeneration or hand cyclone seeding after scarification. The jury is still out as to the success of these methods.

Artificial regeneration following scarification is expensive and present product values are seldom able to carry this cost. Therefore, planting is generally considered only if all else fails. At this moment the state legislature is debating whether to provide minimal funds for the state forest nursery!

Limited research on birch regeneration seems to indicate that with proper scarification, more than sufficient seedbed area to regenerate birch can be provided to meet forest management prescriptions. Scarification must be done so as to expose mineral soil but not destroy the top-most soil horizon by penetrating too deeply.

Improving efficiency in logging and milling practices to make them competitive worldwide, developing industry use of the hardwood component, reducing the dependence on the white spruce, and getting a share of established markets should bring opportunities for intensive management to these interior forests.

The state currently makes available to local industry approximately 247 500 m^3 of wood per year; 64% of this volume comes from the state's interior forest ownership. Generally, the harvest method is clear-cutting, with selective logging being used in white spruce stands when personal-use house logs are involved. Close coordination between personal use sales and commercial sales is a necessary part of the harvest program, preventing high grading of our white spruce stands.

Due to increased bark beetle activity, spruce salvage programs have become increasingly important in recent years. Beetle activity is often associated with wildland fires, which have burned over more than 400 000 ha annually in Alaska since 1940. Almost every acre in the interior has been burned at one time or another, yet this region of Alaska still has an outstanding forest resource. Even under the reduced growth caused by fire and insects and disease, it is estimated that net yearly growth could be 18 million m^3.

What might be the potential if forest managers, instead of being custodians, applied intensive forest management practices to forest lands? If Alaska would take advantage of recent research in harvesting techniques, tree genetics, chemical control of pests and competing vegetation, and regeneration techniques, there is a probability that industry would invest in this source of raw material. We could then develop the resource, maintain or even enhance associated values, and still have industry realize profits even under present economic constraints.

RESEARCH NEEDS

Although Alaska's forest growth rates and rotation ages are considerably less attractive than those attained elsewhere in the world, they do compare favorably with similar forests in Minnesota, Michigan, Canada, and Scandinavia, places that have impressive track records in the development of their forest potential. We in Alaska have spent little time or funds applying what has been learned elsewhere; a coordinated effort by all resource management agencies in applied research is necessary if we are to stretch our limited funds and see results in the shortest time frame.

Some of the information necessary for basic resource management includes inventory data, which provide reliable per-acre volume estimates by species and type as well as effective methods for site classification, and identification of problems associated with each site unit, such as environmental constraints, silvicultural prescriptions, and species selection for regeneration.

Resource measurement data such as standard volume tables, polymorphic site index curves, and yield tables need developing or updating, and this effort has to be coordinated between the researcher and forest manager. Now that Alaska is in the middle of a recession, obtaining the funds and personnel to achieve the forest inventory and measurement is difficult at best. If the right people were convinced that the cost of these activities is an investment today that will produce new wealth in the future, who knows what we could expect for forest management in Alaska?

With such renewed interest, there is a high probability that our struggling forest nursery program would be fully funded and our embryonic cooperative tree improvement program would become reality. These might sound like programs that should be well-established by now, but take into consideration the following points: 1) our forest inventory has been an on-and-off program for the last 10 years; 2) our reforestation budget has never been funded by the legislature (even though it is based upon a percentage of stumpage receipts collected annually); and 3) forest management funds lag dramatically behind fire protection-suppression expenditures. Forest managers plan to weather the current recession with hopes of moving forward in the future by demonstrating the need for the essential forest management programs. The pace of this forward movement will depend heavily on the decline of oil revenues and the realization by government that the development of other resources is essential to maintaining our present standard of living. Development of seasonal economies, based on tourism and fishing, cannot alone meet our needs for the future.

Even if this sounds like we are concluding on a low note, we would like to emphasize that there still exists in the interior of Alaska a world-class resource that should be placed under management. It will become world-class, if multiple use, as defined by future leaders, includes intensive timber management rather than considering timber production to be an undesirable use and incompatible with the other traditional forest uses.

ACKNOWLEDGMENTS

Assistance in preparing this paper was graciously given by J. Davis. Suggestions by the Division of Forestry, Southcentral Regional Staff, are gratefully acknowledged.

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PROBLEMS OF MIXEDWOOD MANAGEMENT

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Recently I was listening to a motivational cassette tape. According to the tape a person should never call a problem a problem because it conjures up all kinds of negative emotions and feelings and blocks the subconscious from providing solutions.

The tape went on to say that we should look at a problem in a positive manner as an opportunity, as a challenge, or (at worst) as a situation that needs to be dealt with. I would like to look at mixedwood from these three perspectives.

Let us look at the opportunities of mixedwood management. The most obvious one is the achievement of higher merchantable volumes at the time of harvest. In many cases, yields per acre are doubled when both the hardwoods and softwoods are taken. This has some effect on reducing falling and skidding costs and substantially reduces road costs and the associated environmental impact.

If both hardwoods and softwoods are utilized, additional land base is opened that was previously uneconomical when only softwoods were taken. This has a cost impact on main-haul road costs and provides a higher than average tree size due to the open-grown nature of the stand.

Mixedwood stands provide more stability for the industry because hardwoods and the softwoods are going into different products and different markets. To some degree the mixedwood will help avoid the traditional roller coaster mill nets the forest industry faces.

I think we are fortunate that the opportunity to use both hardwoods and softwoods has come along. As evidenced by current lawsuits in British Columbia over logging residuals, the public is becoming very concerned about our utilization practices.

The foregoing points are just some of the opportunities of the mixedwood resource, but I think it is obvious that the incentive is there to accept the challenges mixedwood presents.

As I see it, we have two types of challenges. First are the operational challenges to utilize the crop we have out there now. The most prominent in this category is that, in many cases, cutting rights for the hardwoods in a mixedwood stand are held by one party and the softwood rights are held by another party. If a mixedwood forest is to be harvested in one pass, it will be a challenge to meet the expectations of the two different tenure holders.

The companies want to have good neighbors and be good neighbors, but a number of impediments can crop up. The companies have to coordinate their production according to their facilities, markets, and product lines. There are differences in logging methods and logging costs. Delivery schedules differ from one plant to another. Some companies rely on winter hauling only, while others haul year-round. As you can see, coordination between two companies is not completely straightforward and requires a revaluation of traditional practices and economics.

Harvest planning has to remain flexible enough to accommodate situations in which all species are taken in one pass or (in the event that such arrangements cannot be made) one operator can follow the other. It is imperative in this situation that the cutting authority, with its associated responsibilities and liabilities, be transferred from one operator to the other in a very short time frame.

Within an operating area the spheres of interest of the two operators usually do not coincide completely; therefore, a hardwood operator may establish a good working relationship with one softwood operator one year and the next year find himself dealing with someone else. Even with good working relationships, it is difficult to coordinate the harvesting crews to accommodate these changes.

The second type of challenge is to tie the current operational situation into the longer-term timber supply.

Supply levels and annual allowable cuts are based on a broad inventory and a number of criteria and assumptions; attempts to apply this broad information to an operational situation are not always successful. For example, the broad inventory dedicates certain stand types to be hardwood-cut. On the ground, we find that some of these stands contain merchantable quantities of softwood. Now the question arises of whether the softwood belongs to anyone or if it should be charged to the softwood annual allowable cut. Decisions need to be made either completely on the broad inventory or completely on the operational inventory; using a combination of the two leads to confusion. If we are going to use operational information, at some point the decisions have to be tied back to the broad inventory. We have been living in luxury because there has been sufficient uncommitted timber to provide flexibility with operations. This luxury is quickly disappearing as more and more of the resource is allocated.

Assuming we can answer the foregoing challenges, at some point we need to balance the annual allowable cut for hardwoods and softwoods. We have been doing this in pure stands every 5 years. If operations are predominantly in the mixedwood, the 5-year cuts may not balance with the overall long-term annual allowable cuts for the management area.

Let me now move on to reforestation. As more and more mixedwood is cut, we must decide the type of regeneration needed to sustain the annual allowable cuts. The policy so far has been that if a stand is merchantable on a coniferous basis, it should be reforested to conifer, the logic being that the aspen will come back anyway. This policy shows a definite bias toward the softwood. We should be taking a more proactive management position.

I do not think we are at a level of expertise where we can effectively regenerate and manage a mixedwood stand. We need to have one land base for hardwoods and another for the softwoods. In the longer term, yield curves should be used to decide on the number of hectares in each land base required to sustain the cut. In the short term, however, the best method would be to reforest the area in proportion to the volumes of hardwood and softwood removed; this way you could choose the best sites for a particular species. For example, suppose 500 ha of mixedwood were cut in a given year and 40% of the volume removed was softwood and 60% hardwood. At the end of the year, the area would be reviewed and 40% or 200 ha would be chosen as best-suited for conifer, and 60% or 300 ha would be chosen for hardwood. Efforts could then be concentrated on these areas to ensure full stocking is achieved. Future stand tending would then be more straightforward.

In order for this scenario to succeed, the current regulation on reforestation responsibility would have to be modified to give both hardwood and softwood operators reforestation responsibility for hardwoods and softwoods.

This brings me to the situations that must be dealt with. The way I see it, we are not going to be able to make rational mixedwood management decisions until we have some realistic comparative values for hardwoods and softwoods. The figures need to be not only in terms of current value, but also in terms of projected future values. We would have to include the biological factors on tree growth and also the production costs and market values. This is not a simple task, nor are the results static, but we need some sound basis for decision-making, because we are going to have to give preference to one species over another in the mixedwood forest.

The next situation that needs to be dealt with is, in my view, very serious. We need to get on top of the situation. Foresters have been wishing for hardwood utilization for a long time, but now the entrepreneurs, engineers, and sales people have made utilization of the resource take off, and forest managers are being left in the dust. We are going to have to move fast in order to keep up. We cannot let tradition and red tape get in the way of good management.

The last situation I would like to address is the tenure system. Quite a lot of what I have spoken about relates to a situation of two separate tenure holders in the mixedwood, because this is the actual situation out there today. As time goes on we should be looking to amalgamate the land base or harvesting rights under one dual tenure disposition. In order to achieve full advantage of the opportunities mixedwood has to offer, management has to be under the direction and operation of one decision maker. This will evolve naturally to some extent, but government policy, regulation, and development proposals should be trying to encourage this as much as possible.

I would like to conclude by saying that foresters have a once-in-a-lifetime opportunity to bring into play a much greater profile of our forests. Through new technology, industry is moving quickly to utilize the mixedwood resource. It is incumbent upon us to rise to the challenges, put aside our biases, think judiciously about what we are doing, and then move.

MANAGING ASPEN IN THE MIXEDWOOD FOREST

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INTRODUCTION

When I was asked to present an address on aspects of managing in a mixedwood forest—from aesthetics to wildlife, from soil to policy and regulation—I panicked, because I knew the participants would not want to sit and listen for days. Luckily for all of us, my address was limited to 20 minutes. From the broad objectives, I have narrowed my address to a discussion of aspen management in our mixedwood forests. I have chosen aspen as the basis of my presentation because I am sure many of us have worked with softwoods for years.

According to the Alberta Forest Service's Timber Management Branch, in our provincial productive land base, coniferous stands occupy 8 691 162 ha, mixedwood 3 670 321 ha, and pure deciduous 6 037 369ha. This translates into a coniferous annual allowable cut of 14.5 million m^3 and a deciduous annual allowable cut of 11.6 million m^3.

The basis of management is inventory. Alberta's timber resource was inventoried by Phase 3, a photo-interpreted, ground-verified forest cover inventory based on volume sample regions. The aspen volume has been separated from other associated deciduous species, such as black poplar and birch.

The province manages timber by management units. Each management unit has a timber plan that includes annual allowable cut and other resource considerations.

Aspen is a very compatible tree and is found with every conceivable combination of tree species. Pure deciduous stands have the annual allowable cut based on peak mean annual increment, which is generally a rotation age of 60 years. Mixedwood stands are somewhat more complex because they contain coniferous and deciduous species that have two different mean annual increment peaks and resulting rotation ages. Currently, the coniferous mean annual increment is used in mixedwood stands and the stands are programmed for harvest on this basis. We know that this is not maximizing the deciduous annual allowable cut.

Alberta is on the first-cut cycle, so the aspen being harvested is older than its mean annual increment rotation age. Most of the pure deciduous stands are mature to overmature.

The Alberta Forest Service calculates the annual allowable cut for aspen based on the management unit plan and the strategy for that unit. The three principal methods for calculation are as follows.

1) Total deciduous growing stock—all aspen is included from pure aspen stands and mixedwood to coniferous but including incidental aspen. The merchantable threshold in mixedwood stands is 50 m^3/ha for all combined species.

2) Deciduous bias—all pure deciduous and mixedwood stands that are predominantly aspen.

3) Pure deciduous—only pure deciduous stands that have less than 50 m^3/ha coniferous timber.

Long-term aspen harvesting rights are administered through forest management areas and deciduous timber allocations. Timber harvesting for both authorities is carried out by annual operating plans, and timber harvesting ground rules guide the development of an operating plan. The timber harvest plans are based on a field inventory, which is used to develop a merchantability and operability map. This is combined with other inputs such as industrial uses, watershed, recreation, and wildlife. Wildlife referrals are made to Fish and Wildlife biologists to ensure their needs are addressed. The combination of all these inputs culminates in a cut layout map showing harvest areas for coniferous removal, although many of the stands are mixedwood.

Alberta mixedwood management problems have developed from historic operational methods and attitudes. The problem is that coniferous and deciduous timber grows on the same land, which we call a mixedwood forest. This is not a problem in itself, except that the two types have different rotation ages and most forest industry companies use only one or the other species. During industry extraction of a preferred species, a secondary species is subject to falldown from mechanical damage. Also, the first harvest is subjected to higher logging costs incurred by protecting the secondary species.

The Alberta Forest Service is trying to resolve this problem by encouraging a positive program for company wood exchanges. The major problem with wood exchanges, although often camouflaged by other factors, is that companies do not want to provide another company with a real or perceived competitive edge. The provincial government must accept its responsibility for optimizing our resources; the bottom line therefore will be development of harvesting policies and legislation that will force companies to exchange secondary wood to get their primary species. In fairness to the companies associated with this problem, there have been some recent cooperative approaches, but there are significant gains yet to be made.

The integration of mixedwood harvesting is best optimized by overlapping coniferous and deciduous harvesting rights owned by one company. Millar Western industries Ltd. and Pelican Spruce Mills Ltd. have overlapping harvesting rights on several of their operating areas, and the recently announced Daishowa Canada Co. Ltd. and Alberta Newsprint Company Ltd. projects will also utilize both species group. These overlapping harvesting rights and demand for both species will lead to one-phase logging, optimizing our timber resources on the first harvest.

One of the long-range impacts of our present deciduous harvesting is the destruction of understoried spruce. Present logging methods and equipment generally do not protect the understory. This has a long-range negative impact on our coniferous annual allowable cuts. The technology and skills are there to protect this important segment of growing stock; however, its value must be recognized to justify the increased logging costs. For example, we know that a feller-buncher has a higher damage factor to understory than hand felling and cable skidding, but logging systems tend to be rigid for a variety of reasons. Field foresters from industry and government are faced with difficult decisions with understoried stands. If the aspen is logged now, there will be understory destruction, but on the other hand, if the aspen is deferred from harvest until the spruce is mature, it will be beyond any salvageable use. Aspen logging can be an effective tool to release the understoried spruce; however, industry must come up with a new approach and attitude to protect the understoried species.

Aspen cull is a problem. This negative impact can be somewhat lessened by improving our planning. Our overmature stands cannot be bypassed for an operator to obtain his preferred tree. These older stands must be allocated to the best product use. (I know I said this before, but it is a must.) This will mean more wood exchanges among companies. There must be room to barter a large aspen log with center rot to an oriented strand board plant in exchange for small-diameter sound aspen to a pulp mill. Barters like this will optimize our wood resource. Silviculture programs will be developed to recycle the crops of decadent aspen stands that have no recovery possibilities. The recycling process, besides starting a future timber crop, has many wildlife benefits.

I originally thought aspen cull prediction could be accomplished by a system of external indicators such as site and age. The Alberta Forest Service, aided by the Canada-Alberta Forest Resource Development Agreement, devised a program of this nature. Its goals were to predict or develop a stand-product allocation system with size, appearance, and cull as input factors. This would provide an information base to program stands to their best use. Whitecourt has analyzed 1825 trees and 6000 disks. The primary analysis shows that aspen has no guaranteed predictable relationships among age, size, or cull to program trees before sectioning. This indicated that unless the stands are totally over the hill, companies will need to develop mutually beneficial wood exchanges to obtain maximum use of the resources.

Coniferous crop establishment on a pure coniferous land base is not as complex as mixedwood. Mixedwood, on the other hand, is more difficult. First, there is the problem of aspen residual if we are reforesting a block that had only the spruce or pine removed. This creates a scarified area, which is usually planted. A successful planting or seeding project has another barrier to success: the prolific and fast-growing nature of aspen. In selected stands, we are stand-clearing to ensure the success of the coniferous crop. Even in some pure pine sites, aspen is invading and becoming the dominant tree on many cutovers.

The following preliminary data on aspen invasion comes from an ongoing study on stand dynamics after harvesting, which is being conducted by Stan Navratil of the Canadian Forestry Service. The block was harvested in the winter of 1976-77 and drag-scarified in the summer of 1977. The measurement plots were established in 1983. The results were as follows:

1983: 8% aspen, 2% pine
1985: 25% aspen, 8% pine
1987: 30% aspen, 30% pine

Aspen is clearly winning the battle for the site.

Our juvenile stand surveys show that 50% of Alberta's reforested areas on cutovers 10 years and older are reverting to high-density hardwoods, with another 14% to mixedwood. The range of hardwoods is 2100-4580 stems/ha, and some as high as 15 000 stems/ha. Aspen reforestation is very easily accomplished naturally on cutovers. Aspen is a primary invader after wildfires on many sites. The Timber Management Branch of the Alberta Forest Service is developing stocking standards for aspen and an appropriate regeneration survey for pure deciduous reforestation. Another area being reviewed is new reforestation standards for the mixedwood cutovers. There is an obvious concern for coniferous reforestation when developing this policy. Our present stands provide for up to 10% deciduous stocking; however, the high regeneration capability of aspen is overshadowing our preferred coniferous species.

Mixedwood management is increasing in importance with the management of our forest resources. Aspen is today's star and new partner in our mixedwood management.

WHAT DID YOU EXPECT?

S.M. Smith
Weyerhaeuser Canada Ltd.
Prince Albert, Saskatchewan

INTRODUCTION

Weyerhaeuser Canada Ltd. has recently begun utilization of hardwood species, in addition to traditional softwood consumption, at its Saskatchewan Division operations. Forest management and regeneration problems are not eliminated by virtue of all-species harvesting. This paper outlines the company's experience and approach to the mixedwood region of Saskatchewan.

Previous speakers at this conference have described the problems associated with harvest of only the conifer component or the deciduous component from the mixedwood forest. Let me assure you, the problems are not entirely solved by the utilization of both species.

The Weyerhaeuser Forest Management Licence area appears to be ideally suited to meet the demands of its current mills—that being a sawmill at Bodmin, near Big River, requiring 280 000 to 300 000 m^3 annually and a kraft pulp mill at Prince Albert requiring approximately 1.0 million m^3 of softwood and 620 000 m^3 of hardwood. This represents a species split of 67% softwood and 33% hardwood. The Long Run Sustained Yield for the Core Area (similar to an annual allowable cut) is made up of 1 021 000 m^3 of softwood and 722 000 m^3 of hardwood, for a total of 1 743 000 m^3 and a percentage split of 59% softwood and 41% hardwood.

There is an apparently attractive supply-demand relationship. The difficulty soon becomes apparent when we consider the present volume of purchased chips and roundwood, most of which is softwood amounting to about 700 000 m^3 and arising from outside the lease area (which is very attractive from a cost perspective). The difficulty is also obvious now as we are attempting to increase private hardwood purchases.

The net result, in 1988, is planned wood production for our lease area as follows:

Hardwood pulp: 433 000 m^3
Softwood pulp: 265 000 m^3
Softwood logs: 253 000 m^3

Total: 951 000 m^3

Again, this can be expressed as 55% softwood and 45% hardwood.

Looking back at the available wood supply, it is evident that the forest cannot be harvested in the proportion in which it occurs without substantially overproducing softwood. In fact, the only way to meet the current timber requirements will be to essentially log only in the hardwood and predominantly hardwood timber types.

More realistically, the utilization of both hardwoods and softwoods from the mixedwood forest offers opportunities in some parts of the area and on some sites but, unless the species balance is in perfect proportion to the long-term mill consumption, selective emphasis in the harvesting, regeneration, and management of designated species will continue.

MANAGEMENT PLANNING

The commencement of hardwood utilization, in conjunction with an expanded sawmill production, has revealed the importance of reliable, accurate, and up-to-date forest inventory information. The previous experience of general volume conservatism is now of little consolation as we must predict with some accuracy the percentages of softwood pulp and hardwood and softwood logs that will be produced from a given harvest block. Furthermore, current exploration of harvest-growth computer simulation programs, such as the Weyerhaeuser High Yield Forestry Model, demand inventory detail about the projected future forest, considered a luxury only a few years ago. I also point out that the historical insignificance of the hardwood species is reflected in Saskatchewan's provincial forest inventory sampling, and we often find softwood harvest yields more in line with the inventory than hardwood yields. New and intensified sampling is required in many aspen-predominant and mixedwood types.

UTILIZATION

Merchantability limits for the hardwood species differ only as a result of the branching habit of aspen. Top diameter is determined by the point at which crown branches begin, rather than by some agreed-upon standard, as is the case with the softwoods.

Stand utilization is somewhat more of a problem and varies with distance from the mill and also with current mill demands.

Clear-cutting of all mixedwood stands is just not possible. This would result in excess hardwood volume being produced at the outer extremities of the lease during the course of sawlog harvesting, and there would be a corresponding need to bypass hardwood or mixedwood stands close to the pulp mill. The more realistic option is to clear-cut stands closer to the mill until a substantial proportion of total wood requirements have been met and then to begin selective logging for the remaining volume. The difficult question remains as to when the residual stands can be scheduled for harvest and what is an acceptable delay in regeneration treatments.

REFORESTATION

As in most of the industry, our reforestation experience is greatest with the regeneration of softwoods and, to some degree, the suppression of competition—the hardwoods.

We have had to redirect our focus on the hardwood resource, which has not been an easy task. The future objective is not merely to allow hardwood regeneration to occur, which we all believe will happen naturally if we just ignore harvested areas entirely, but to encourage and cultivate the hardwood resource with the same intensity as is directed at its softwood counterpart.

Do we not all believe that the same type of management techniques that will generate higher quality and yield responses in conifers can be applied to the hardwoods? This is not a trivial psychological obstacle to overcome.

In Saskatchewan, a number of different approaches are under way. These include looking at the occurrence and performance of both hardwoods and softwoods on currently regenerating cutovers.

Former regeneration surveys focused only on the softwoods, noting competition on the tally sheets. Now, all species are tallied and some interesting aspects are coming to light. Some sites, previously considered understocked or marginally-stocked can now be called adequately stocked when the hardwoods are counted. In fact, some of the previously considered nonsatisfactorily restocked total has magically disappeared in this context!

On the negative side, however, we are realizing that the vegetation considered competition in the past is often a mixture of trembling aspen, black poplar, willow, alder, birch, and dogwood. This is the first inkling that perhaps desirable hardwood regeneration is not free after all.

Next, regeneration survey results for hardwoods were linked back to certain silviculture treatments. We found that the use of a Marden drum chopper, for example, led to different results under different conditions. In one instance, the chopper was used to destroy young hardwood suckering prior to establishment of a white spruce plantation—the prescription in that case. At the time, the need for a follow-up herbicide treatment at age 4 or 5 was acknowledged, as a positive response to the chopper site disturbance was expected. To our surprise, only scattered alder and grass recovered. In other situations, however, the more commonly expected occurred-rapid and profuse hardwood regeneration followed drum-chopping. The crushing of logging debris, disturbance to root systems, and subsequent raising of soil temperatures promoted hardwood regeneration. Both of these treatments preceded softwood plantation establishment but affected hardwood regeneration differently.

Another treatment involved the use of a Bracke cultivator. In this instance, the treatment was carried out in the second growing season following harvest of a pure aspen stand. The patch-scarifying action of the cultivator acted to interrupt the naturally occurring aspen root sprouts, so that there was regeneration between the scalps but not in them, unlike the response on softwood cutovers where regeneration occurs in and around the mineral-soil scalp. Aspen sprouts, measured at age 5 years, totaled 19 000 per hectare on the control site and 14 000 per hectare on the scarified site, indicating the obvious influence of the silvicultural treatment. Is it significant? Is it beneficial?

We have now initiated studies to determine the influencing factors—time of year of cutting, time of year of treatment, type of treatment, age of previous stand, and so forth. We want to understand how and why hardwood regeneration responds as it does and to use this understanding to improve both our hardwood and softwood regeneration efforts. Projects involving new site preparation tools, such as the Donaren, TTS, and Waddell scarifiers (supported by the Canadian Forestry Service (CFS) through the Canada–Alberta Forest

Resource Development Agreement), thinning projects comprising part of the growth and yield program, and other special studies of our own and CFS origin will all assist.

A third approach has been the tree improvement efforts begun at Prince Albert 12 years ago with the establishment of a jack pine seed orchard. This was followed in 1981 with a white spruce orchard. Last year, we began experiments in rooting trembling aspen from cuttings. The rooting experiments were initiated to develop some background in methodology, while other field investigations continued to confirm the adequacy of regeneration on aspen cutovers. Trembling aspen is known to be one of the most difficult species to root from cuttings, so a variety of approaches was undertaken, including misting in the greenhouse, growth hormones, and different ages of cuttings. If, as we expect, complete and adequate natural regeneration of aspen is not guaranteed, the groundwork will have been laid for an artificial mass propagation program.

At the same time a variety of prairie region hybrids, mostly cottonwood species, were outplanted to assess performance against native populations. Pulping trials using poplar hybrids do not usually reveal any superiority of fiber or sheet characteristics over the native aspen and poplar. Nonetheless, limited trials of these hybrids will continue, perhaps with more applicability for establishment on private land.

OTHER RESOURCE USERS

Closer utilization of all species on the forest land base has the effect of intensifying competing uses for land. In timber stands once left uncut and therefore suitable for wildlife habitat or for human recreation, all of the productive forest land is now being scheduled for some form of harvesting activity.

Our approach to this new situation is to step up our own involvement and communication with these other resource users to attempt to prevent conflicts from arising. Wildlife studies have also been initiated to understand more fully the interaction of harvesting and game populations.

POLICY AND REGULATION

Due to the more rapid regeneration and development rates of hardwood species, limitations on cutover size are not as stringent for them as for softwoods. The present limit for hardwoods is 130 ha (300 acres) compared to 40 ha (100 acres) for softwoods. Aside from this size constraint, no special provisions or requirements exist in the Forest Act or regulations.

Within our company, we believe there is a desirable balance among what the forest sites can potentially produce, what the species themselves are capable of, and what level of economic input or effort is justifiable. We have not yet determined that balance but expect to have an answer soon.

SOILS, ECOLOGY, AND GEOGRAPHY

In our case, most of the mixedwood belt lies in the southern half of the Weyerhaeuser lease area. The move toward hardwood utilization has not occurred as an expansion of mill output but rather as replacement for softwood production. The net result is that harvesting can be confined to areas closer to the mill—a very desirable situation—and the softwood timber surplus arising from expanded hardwood usage now exists in the lease's distant extremities. This reduced radius has some great potential to encourage prime site management and accelerated silviculture expenditures on both hardwood and softwood areas.

CONCLUSION

The important thing to remember is that the utilization of both softwood and hardwood species should not be perceived as merely a new-found use for the "junk" but as a legitimate reorientation of the marketplace that now places our hardwood resource in a position of value equal to, and, in some cases, exceeding, that of the softwood species. We foresters are used to speaking of intensive forestry where the timber values are highest; consider now that this aspen timber may be our country's ultimate salvation as a forest resource supplier.

HARVEST OF SPRUCE AND ASPEN IN THE HUDSON BAY REGION: THE JACK SPRATT PRINCIPLE

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INTRODUCTION

To this point we have discussed problems of harvesting one species or the other from mixedwood forests. In one area of Saskatchewan we have had hardwood and softwood harvested and utilized by two companies for 25 years. I hope the seminar organizers do not expect that we have all the answers, because I am here to tell you that we do not—not yet, that is. We do, however, have considerable experience with two companies harvesting from the same area, and we do know some of the things that need consideration when integrating the operations.

Let us look for a few moments at our example. The Hudson Bay area is in the mixedwood ecodistrict (Harris et al. 1983) of the southern Boreal Forest Region ecoregion (Rowe 1972). The region abuts the Manitoba border about halfway up Saskatchewan. There are large areas of hardwood and mixedwood, but not many patches of softwood. There is very little pine in the Hudson Bay area. From this area, two companies are harvesting their wood requirements.

Of particular interest is that large, compact areas of hardwood are available for harvest within a short radius of Hudson Bay. Due to the paucity of softwood stands, the softwood must be harvested from mixed stands and must also be brought in from great distances.

BACKGROUND

Industry

Up to the mid-1960s the bush sawmill reigned supreme, sawing large softwood trees and using selective harvesting by diameter sizes.

The first-ever waferboard plant was built in Hudson Bay in 1961. Later it was purchased by MacMillan Bloedel, which doubled its capacity in the late 1960s. Close on its heels was the Dumont stud mill, which Simpson Timber purchased, then expanded in the late 1960s. Both companies have since upgraded their mills. In 1974, Saskatchewan Forest Products Corporation built a plywood mill, and Simpson retooled to suit the smaller log sizes available to it.

Modi Operandi

The *modi operandi* are very different for the two harvesting companies, and it is important to understand this before we talk in more detail about practicalities of mixedwood utilization.

MacMillan Bloedel (Sask.) Ltd.

MacMillan Bloedel has the rights to the poplar forest, which is defined as hardwood and predominantly hardwood. Its agreement area is within a radius of about 50 miles of Hudson Bay.

Due to the concentrations of poplar, MacMillan Bloedel is able to hire a few large contractors year-round. The company builds roads and landings using one contractor, who pre-logs the sites. The company has a well-defined 5-year plan that shows the cut blocks and roading system.

The company's product is waferboard, so it can use the total tree in its own mill. Logs with butts over 22 inches are sold to a local sawmill operator.

Natural regeneration of aspen is immediate and abundant, and MacMillan Bloedel has addressed problems of regeneration on landings and of hazel brush growth after harvest.

Simpson Timber Co. Ltd.

Simpson Timber Company has a volume agreement and has rights to harvest softwood from a large area, including the MacMillan Bloedel lease, and must also harvest logs from its Creighton supply area, about 230 km north of Hudson Bay.

The spruce is present in smaller concentrations and often beyond wet areas; thus, it is not feasible to construct high-quality extraction roads. Instead, the company's 30 contractors arrange their own access, often using frozen sloughs or widening old trails. A majority of the wood is harvested in winter. Long-range plans are less defined.

This company's product is studs. In addition, it must deliver a specified volume, quality, and size of log to the plywood mill, for which in return it receives the plywood cores. It must dispose of small logs and unusable cores to the pulp mill, 260 km away.

Simpson Timber Company pays into a reforestation trust fund based on volumes sawn. Its plywood mill also pays into this trust fund, which the company must spend on reforestation of its harvested areas.

COORDINATION CHALLENGES

Now that we have mentioned the products and the *modi operandi* of the two companies that are harvesting side by side, we should look at some of the situations that have occurred in the last few years. We can sort these into two groupings. The first group is general problems, andthe second is problems that arise because spruce and poplar grow in the same stand.

General Problems

First we will discuss four general problems: extraction roads, land out of production, clone concerns, and wildlife.

Extraction Roads

MacMillan Bloedel builds all-weather roads, and other commercial users must pay a road-user fee for hauling over these roads. Simpson Timber contractors, who arrange for their own access, often claim that they can improve a nearby bush trail and use that at much less cost or that MacMillan Bloedel builds over or blocks access to a bush road that they would have used.

Planning and approval of roads must be done with care to prevent parallel road systems. A firm understanding must be in place between the two companies that may include times of use, maintenance (including snow plowing), and user fees. If one road can service both companies, why take land out of production to build two?

Land Out of Production

Although MacMillan Bloedel has the rights to the poplar forest, there are some stands it is not interested in logging. These are the open poplar stands, usually derived from past harvesting of the spruce from a mixedwood stand. This leaves a decadent open poplar stand, which, although falling within the definition of a poplar forest, is not of interest to MacMillan Bloedel. How is such a stand to be returned to production? What options are there?

We could leave it, but aspen regeneration would be sparse, thus creating another open poplar stand. As well, the current decadent stand would provide a breeding ground and distribution center for insects and diseases.

We could harvest the poplar, stimulating suckers to renew the stand. But the poplar is decadent and quite damaged from harvest operations, and no one wants to use it commercially. It could be killed using one method or another, but we are not currently using herbicides in Saskatchewan forests.

We could underplant with spruce among the sparse poplar to provide full stocking. The Department of Parks, Recreation and Culture has done this, although it is expensive, difficult, and often unsuccessful.

Provincial emphasis is on renewal of current harvest. Only when we have ceased to create further backlog will we address areas currently out of production. In the meantime, given enough time, some stands may sort themselves out and be back in production again.

Clone Concerns

Some poplar clones may be partially rot infested (Steneker and Wall 1970). Once the parents are harvested, this rot infects the new growth at an even earlier age than usual. Will this in time degrade the quality of the poplar forest? Will we ever need to plant poplar hybrids, and if so, how will this be done? This is an area that requires further study.

Wildlife and Cut Size

In the past, cutover size and patterns have been of concern to wildlife officials. The optimum is, of course, to provide as much edge as possible, with some cutover areas for wildlife to feed in and some forest nearby to provide shelter from the elements. In Saskatchewan we currently limit clear-cut sizes to 40 ha for softwoods and to between 120 and 400 ha for hardwoods.

If we have a 40-ha softwood cut and someone applies to cut the nearby poplar, which limitation applies?

In such sizes we should be matching the cutover sizes to the type of vegetation, topography, state of the forest, and so on.

Growing Together

The second broad area we should consider contains questions brought up because hardwoods and softwoods grow together. As with boys and girls, you cannot keep them apart: instead you set appropriate mores for them being together.

Understory

The first dilemma to surface was spruce understory in mature poplar stands. Due to the comparative scarcity of spruce and the expense and difficulty of regenerating it, it is upsetting to have it destroyed by poplar harvesting. On the other hand, it is on the MacMillan Bloedel lease and the company has the right to harvest this poplar, although at first MacMillan Bloedel was kept out of such stands.

The Canadian Forestry Service (CFS) studied this situation and showed that with careful harvesting methods enough spruce could be left to provide a reasonable number of stems for the next rotation (Froning 1980)—but the contractor has increased costs (Gottfield 1987). Who should pay these costs? Of course, no one volunteered. A partial answer to this problem was found when mechanized harvesters were brought in. It was found that feller-bunchers and grapple skidders did much less damage to the understory than single tree harvest, without seriously modifying the skidding patterns. Understory will continue to be a difficult situation.

Harvesting Windows

For spruce the harvesting window is generally between 70 and 150 years of age (Kabzems 1971), and for studs this can be narrowed to 90 years or more. For poplar, the window is between 70 and 105 years of age (Kirby 1962). Obviously, the age when MacMillan Bloedel prefers to harvest the aspen (70 years) does not fit the same rotation as spruce for plywood and studs. When the two are growing together, therefore, a decision must be made about time of harvest. The following issues need to be considered:

- Should poplar be harvested at maturity before it gets too rotten? What happens to the spruce?

- If spruce is harvested at the same time, it will be tall and thin, thus producing a fair amount of less-desirable product (i.e., pulpwood).

- If spruce is left for 20–30 years to mature and increase in diameter (Gottfield 1987), there will be more decay (introduced after logging damage), and the spruce harvest will damage the aspen regeneration, which will then be 20–30 years old (Hinds and Shepperd 1987).

- Alternatively, should the whole stand be harvested at spruce maturity? Can the poplar then be utilized?

The answers to these problems vary, depending on the percentage of each species, the size of the stand, proximity to spruce and aspen in the area, and the size of the spruce.

To be realistic, plywood-sized logs will not be available in the next rotation. As the poplar and spruce harvesting windows do overlap, in the long run we will have to work something out that is suitable to both harvesters.

Spruce Availability

At first there is no problem for a spruce harvester, as there are numerous stands of pure spruce and predominantly spruce. Eventually, however, there become fewer and fewer of these, and a greater percentage of the softwood must be harvested from predominantly poplar stands. How should this be done?

Should spruce only be harvested? This is possible if the spruce are in small, pure clumps. If the spruce are scattered evenly through the poplar, though, there will be a lot of stand damage and the poplar will be infected with rot and decay by the time it is harvested.

Should poplar that is mixed in with the spruce be harvested? The poplar is the major species, and too much of this by-product could create problems: poplar contractors would need to have their volumes reduced to balance the volumes from Simpson Timber Company contractors, and spruce contractors get paid more than those logging poplar and are not anxious to log poplar at lower prices.

If two companies are to harvest the same area for different species, harvest operations should be as close to each other as possible to reduce the damage to aspen regeneration (Hinds and Shepperd 1987) or to reduce the damage to standing mature poplar, which is susceptible to infestation.

Species Composition

How important is it for the composition of the current forest to remain close to its present configuration?

Stand succession is not fully understood, and in fact it is difficult to estimate from aerial photographs what softwood will be produced from any particular hardwood stand. Young spruce understory is difficult to see on photographs and even more tricky to quantify, although it can be done by special photography (Ball and Kolabinski 1979; Hall 1984).

In all cases of disturbance, do we accept the poplar that will come back in abundance? Opinions vary on the outcome of allowing this, but the fear is that it will cause a gradual conversion to poplar. Does it matter to future industry if this does occur?

FOREST RENEWAL

Having discussed some of the coordination challenges, I would like to describe some of the forest renewal activities that take place in mixedwood areas.

Reforestation

When a healthy pure stand is harvested, there is not much doubt about the reforestation that should follow. But when softwood is harvested from a decadent mixedwood stand, what happens? To renew it to softwood is very expensive, and often there are other areas that can be prepared and planted at less cost.

Most of our reforestation work has taken place after harvest, in areas that have poplar problems. In 1973 our Forestry Branch, assisted by the CFS, studied seven pieces of site preparation equipment to determine the ability of each tool to prepare planting sites in residual poplar stands. Heavy equipment is necessary on some sites from an operational viewpoint, and such equipment includes the C & H plow, a modified V-blade, and most often an angled dozer blade. The last of these is used most often because there are many available, which means that prices are reasonable.

We prefer, if possible, from a biological point of view (LeBlanc and Sutherland 1987) to use less drastic, lighter equipment. The Forestry Branch owns two TTS mechanical disk trenchers, and we have recently contracted with Delta power trenchers with good results. We intend to use power trenchers whenever possible.

On pine sites where plantings may be necessary, we have had very good results with a Madge Rotoclear, which appears to give good survival and growth.

Most of the white spruce planted in the area are 3-0 bare-root seedlings, and there are some in containers (multipots). MacMillan Bloedel plants some of its landings with hybrid poplar.

No stand tending takes place in the Hudson Bay area. Simpson Timber does not have enough in its renewal fund, and the government priority is on stand establishment rather than enhancement.

CONCLUSION

I have described some of the situations that we have been increasingly involved with over the last 25 years. How are we going to benefit from these experiences without struggling with them again?

We are aware that these problems exist, and in planning for industrial development in the next area under consideration—the west side—we are hopeful that we can avoid some of these irritants. We know there will also be some new ones, because the species composition is different—there is a lot more pine on the west side.

We would be thankful to receive one harvesting plan for the area that would include harvest and renewal of all species. This could mean the following:

- one woodlands company to harvest all species and to deliver the required species and sizes to the appropriate processing plants;
- one of the processing plants having a woodlands arm to supply wood to its own mill and to others in the area; or
- two woodlands groups that coordinate their logging and renewal plans prior to submission.

All the above options incorporate the same basic principle: there should be maximum coordination (and, therefore, agreement) among the processing plants prior to plans being presented for approval. The logical people to sort out the process of harvest and renewal are the practical people involved in the business. They must cohabit in the same territory, and through close working relationships with each other they can get the job done cooperatively and follow the example laid down by the Spratts:

Jack Spratt could eat no fat,
His wife could eat no lean;
And so betwixt them both, you see,
They licked the platter clean.

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SITE CLASSIFICATION AND PRODUCTIVITY IN THE BOREAL MIXEDWOOD

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The term mixedwood forest, in the context of this symposium, implies a broader concept ecologically than that encompassed by the Boreal Mixedwood Section (B.18a) of the Boreal Forest Region as described by Rowe (1972). A similar Boreal Mixedwood Symposium sponsored by the Canada-Ontario Joint Forest Research Committee (COJFRC) in 1980 considered the definition of boreal mixedwood (Whitney and McClain 1981). The traditional forest inventory definition of mixedwood cover types are those with hardwoods and softwoods growing together, but with neither representing more than 75% of the stems. We can appreciate that such a definition would encompass stands on a very wide range of environmental conditions and with wide variations in tree species composition and productivity. As Ken Armson has mentioned at this symposium, the Spruce-Fir-Aspen Research Committee of COJFRC defined boreal mixedwood (McClain 1981) in terms of sites that support or could support good growth of the five main component species, namely white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.), balsam fir (*Abies balsamea*(L.) Mill.), trembling aspen (*Populus tremuloides* (Michx.), and white birch (*Betula papyrifera* Marsh.). Sites excluded by this definition are wet, poorly drained lowlands (commonly supporting black spruce), dry sandy areas (commonly supporting jack pine), and excessively drained shallow soils on rocky ridges (commonly supporting jack pine and/or black spruce). Included in the Ontario definition are the many soils of glacial, lacustrine, or alluvial origin. Moisture regimes vary from dry to very moist, depending largely on slope position and soil texture (McClain 1981).

The Ontario definition, I believe, is a good one because it defines boreal mixedwood on the basis of site potential rather than simply present forest cover. The definition should be modified for our region to include lodgepole pine (*Pinus contorta* Loudon var. *latifolia* Engelm.) and jack pine (*Pinus banksiana* Lamb.) on mesic sites where they occur with the other species mentioned. It is apparent that this definition of boreal mixedwood, while more useful than the inventory definition, still includes sites with a wide range of environmental characteristics within several forest sections of the Boreal Forest Region as defined by Rowe (1972). The Mixedwood Section (B.18a) is certainly the nucleus of our broader definition of boreal mixedwood, but also included within the prairie provinces are Lower Foothills (B.19a) and Manitoba Lowlands (B.15) Sections (Fig. 1).

In this paper I am going to concentrate on some of the basic principles of site classification and their potential for use in forest management. In addressing the topic of mixedwood site classification and productivity, it is appropriate to define site. Webster defines site as a location or situation. To the forest ecologist, a site is a location in the forest expressed as the sum of landform, soils, vegetation, and local climate and microclimate (through elevation, slope aspect, angle, and position), and by several internal site properties that are not evident without taking a much closer look at the site. Such internal site properties include mainly soil properties: drainage, profile morphology, texture, structure, color, mottling, chemical properties, etc.

Recognizing that while no two sites are identical as we traverse the landscape, it will be evident that there are similarities between sites with respect to landform, topography, vegetation, or soils. These similar sites can be grouped into ecological systems or ecosystems. Animals, the other important component of the ecosystem, will not be discussed here, but the importance of ungulates in particular in the mixedwood ecosystems is great. Clear-cutting can enhance moose browse abundance, but escape cover is also required (McNicol and Timmerman 1981). An ecological site classification, particularly when mapped, can serve as a sound basis for wildlife habitat management. Ecosystems classified within a forest management context are often referred to as site types.

Why should we bother to classify forest sites? A classification allows us to transfer knowledge and experience gained in one situation to similar situations elsewhere, something that all of us do in our personal and professional lives. A site classification gives us insight into the environmental conditions influencing tree growth and establishment. An understanding and ability to interpret forest site differences is fundamental in an intensive forest management program and will result in saving of money and optimization of effort.

Forest ecologists have observed that the occurrence of various ecosystems or site types can be described and

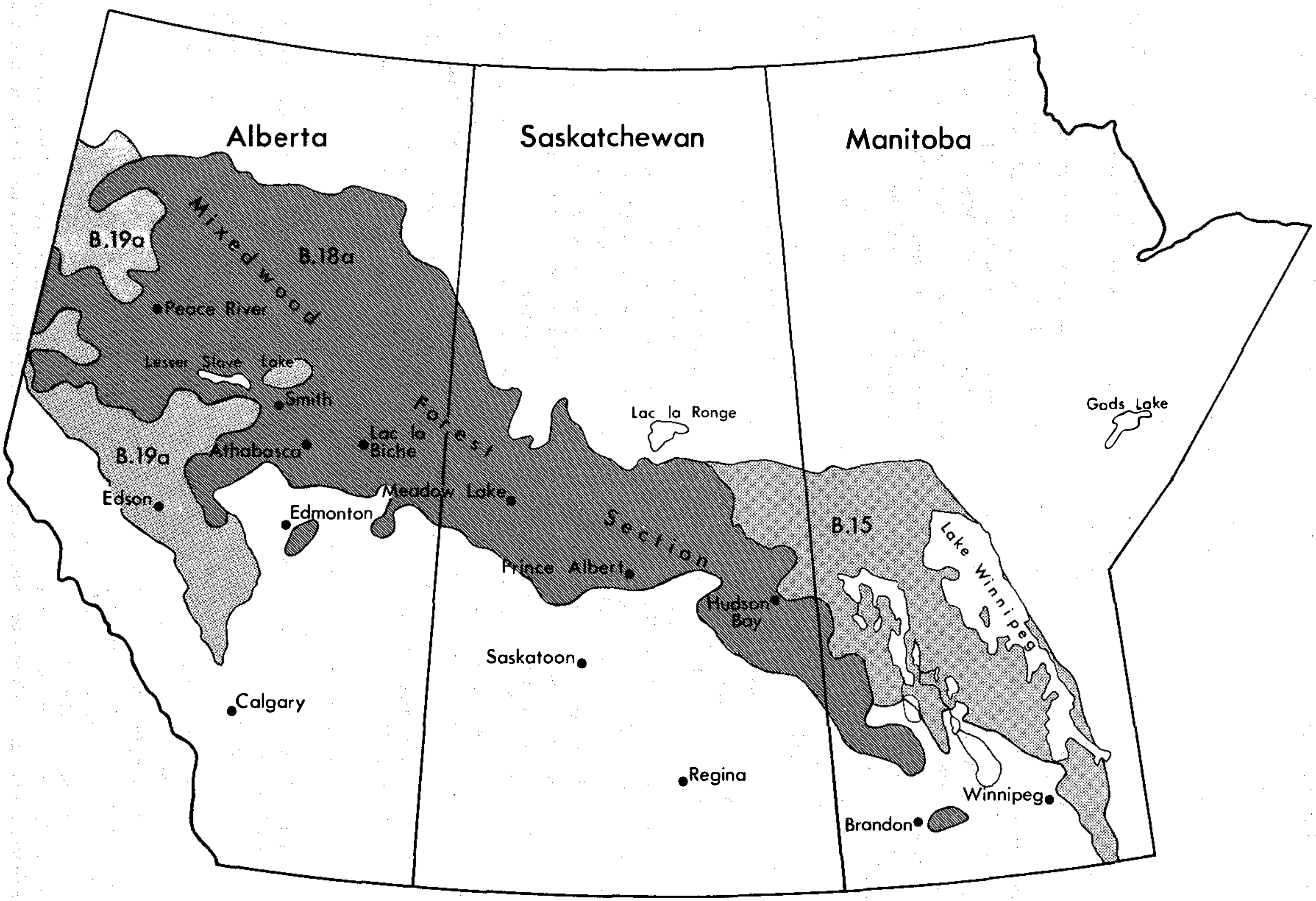


Figure 1. Rowe's (1972) forest sections in the prairie provinces with mixedwood forest cover.

related to each other in terms of two important environmental gradients: moisture regime and nutrient regime expressed on a two-dimensional grid (Fig. 2). These grids, although not quantitative, visually express some important site interrelationships. Moisture regime is influenced by soil drainage, texture, depth, and slope position. Nutrient regime, however, is more difficult to characterize. It is influenced by the type of soil parent material, texture, moisture regime, and seepage.

Site classifications tend to be hierarchical, with information expressed at several levels of generalization. The Canadian Committee on Ecological Land Classification hierarchy, as described by Rowe (1979) and adapted from Lacate (1969), is a typical example (Fig. 3). The uppermost level in the hierarchy is the ecoregion (land region), which is a geographic area with the same regional climate as expressed by vegetation. The second level, the ecodistrict (land district), is a subregional unit where the climatic regime differs substantially from adjacent lands due to altitude (relief) and/or geological substratum (Rowe 1979). The third level, the ecosection (land system), is an intermediate-sized unit whose form expresses a climatic-geomorphologic process (fluvial, colluvial, aeolian, and glacial). The fourth level, the ecosite (land type), is a small topographic unit, one of the associated catenary members of a land system, and uniform in the functionally related local climate, soil drainage, and biota. Sites can be classified by grouping from below (agglomeration) or by subdividing from above (division) (Fig. 4) in such a way that a hierarchy is formed (Valentine 1986). When grouping, few if any map unit boundaries are fixed before fieldwork; in the division approach, most are.

Site classifications may be cartographic (mapped) or taxonomic, in which the site types are described and identified with a key but not mapped. Mapped classifications are generally preferred by the user and have the advantage of being used to relate the site units to other mapped information with overlays or a geographic information system. Site mapping at the scale desired by foresters (1:10 000–1:25 000) is very expensive. Also, map units are seldom pure. The inherent variability in a given map unit must be appreciated by the user. Appropriate large-scale site maps satisfy most users, but costs of mapping large forested areas at large scale cannot usually be justified.

Taxonomic classifications such as the forest ecosystem classifications used in British Columbia (Green et al. 1984), Alberta (Corns and Annas 1986), and Ontario (Jones et al. 1983) use keys to identify site types of forest ecosystems in the field. Such an approach classifies and describes the various forest ecosystems or site types occurring in an area in a cost-effective manner. They also serve as a good base for site-specific forest management prescriptions. The unmapped classifications, while satisfying some of the needs of the silviculturist, are less satisfactory for the inventory forester who depends heavily upon maps.

Although it may not be immediately apparent, both the cartographic and taxonomic systems describe similar units at the detailed ecosite or site type (ecosystem) level. The criteria used for distinguishing the sites must be appropriate to the method used. In mapping, where we rely heavily upon aerial photographs to discriminate among site types, landform becomes an important criterion. In a site-specific classification used on the ground, site properties evident on-site, such as vegetation, slope, and moisture regime, become more important. Vegetation is not classified as an end in itself, but rather the site units are distinguished on the basis of vegetation in addition to other traditional soil and site properties. Separations on the basis of vegetational differences should also be meaningful in terms of separating land units with inherent differences in productivity or response to management. In practice it is possible to implement a site classification that employs the advantages of both the mapping and taxonomic systems; i.e., a mapped site classification that has keys to the ecosystem units that can be identified independently of the maps. This is desirable if the map units contain a large amount of variability that cannot be separated at the scale of mapping used. This latter approach is currently being used by a contractor on two pilot project areas in Manitoba under the Canada–Manitoba Forest Renewal Agreement.

In the time remaining, I will briefly discuss some representative site types in the boreal mixedwood forest of the prairie provinces. Within the area we have designated as boreal mixedwood lies some of the most productive forest land in Canada (with the obvious exception of coastal British Columbia). Gross mean annual increments (MAI) in unmanaged stands in Alberta are in the range of 1.0–6.0 m^3/ha, with some stands producing in excess of 7.0 m^3/ha (Corns and Annas 1986), depending upon site and stand history. Unmanaged boreal mixedwood stands in Saskatchewan have MAIs in the 1.0–5.0 m^3/ha range (Kabzems et al. 1986). The Canada Land Inventory in Saskatchewan revealed an average annual potential MAI in Rowe's Mixedwood Section (B.18a) of 2.9 m^3/ha, while actual production was 1.1 m^3/ha (Kabzems et al. 1986).

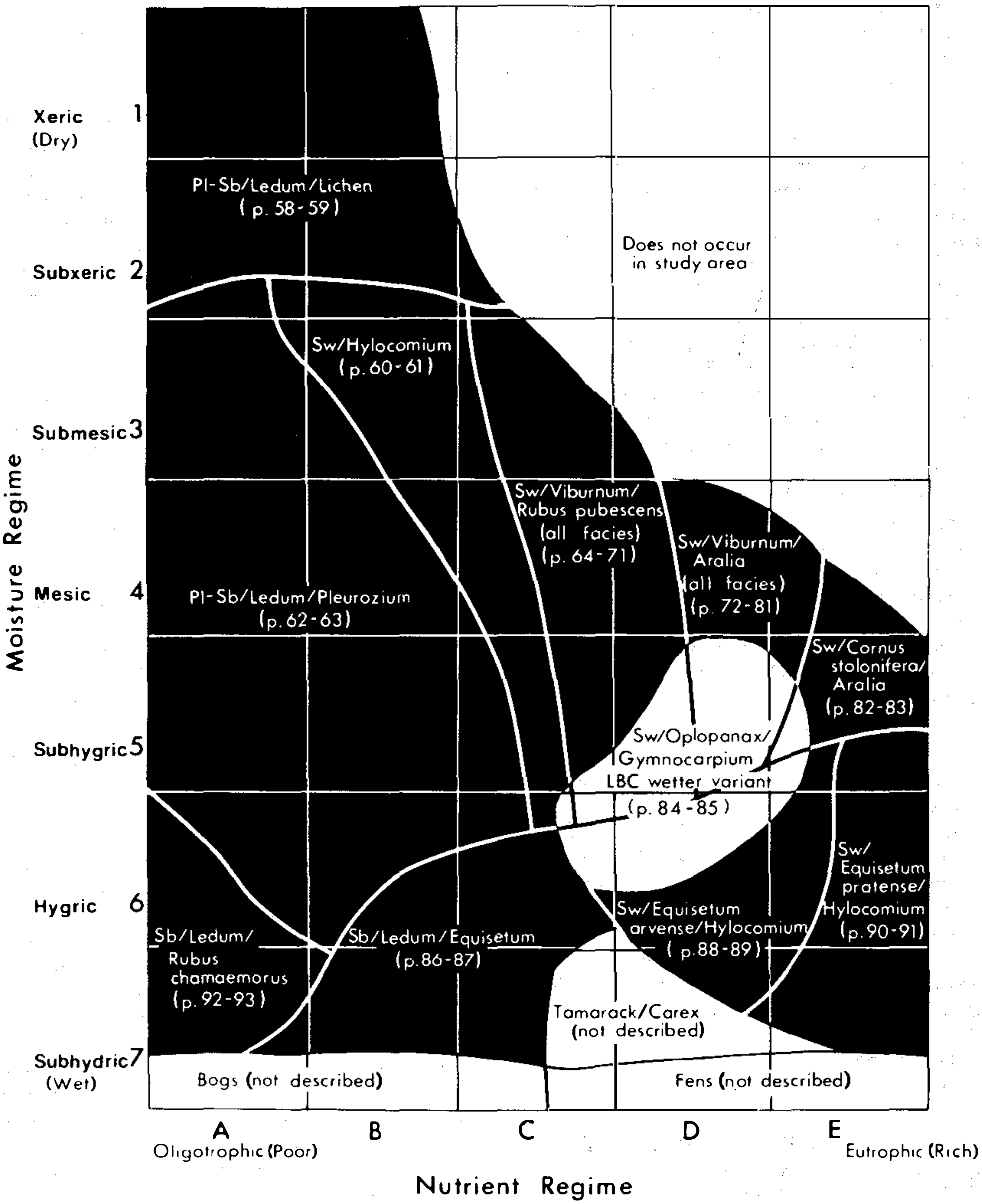


Figure 2. An example of a moisture-nutrient regime grid (Corns and Annas 1986).

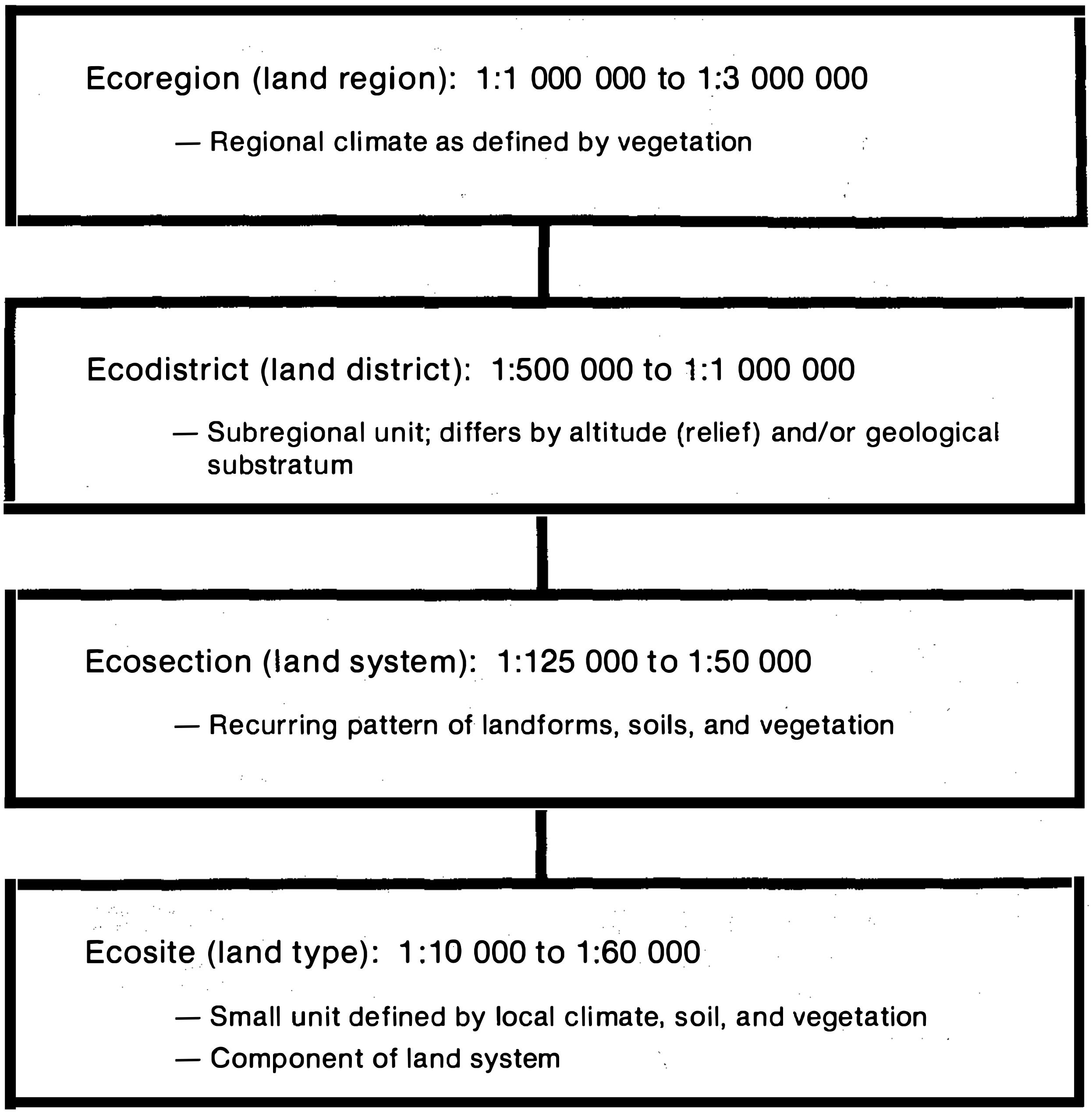
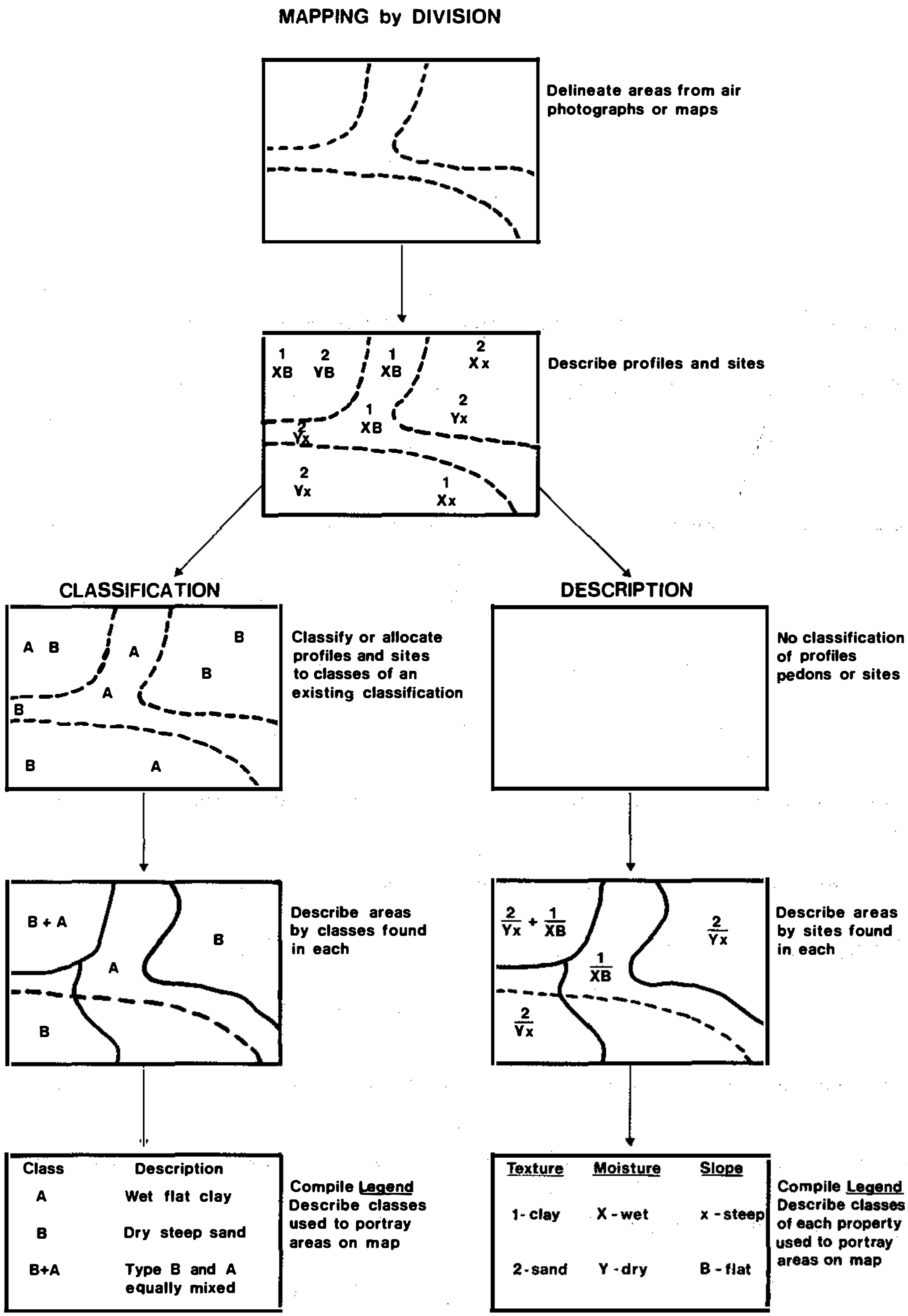


Figure 3. The Canadian Committee on Ecological Land Classification (CCELC) hierarchy (Rowe 1979).



Source: Valentine 1986

Figure 4. Site classification by division (Valentine 1986).

Average productivity in Alberta is similar[1]. In all three prairie provinces a small amount of Canada Land Inventory Capability Class 3 is mapped with a potential annual productivity of 5.0-6.3 m³/ha (Canada Land Inventory 1976). Table 1 shows the range of productivity that occurs within forest ecosystems in the boreal mixedwood forest of Saskatchewan (from Kabzems et al. 1986).

SUMMARY

The boreal mixedwood forest is a mosaic of site types, each characterized by its own set of environmental characteristics and its own dilemmas and opportunities in terms of management. There are also dilemmas and opportunities with respect to the use of site classification information. Dilemmas include the following: 1) site classification information is still unavailable for much of the boreal mixedwood; 2) site information is often not mapped; 3) the user is not comfortable using a site classification; 4) it takes time to quantify management response for various sites; and 5) forest management in our region is still extensive.

The opportunities available, I believe, are greater than the problems and, with time, will greatly outweigh any present obstacles. They may be summarized as follows: 1) a site classification allows us to transfer knowledge and experience from a site to other similar sites in the region; 2) a site classification is the logical framework for forest land management and for conducting forest research; 3) implementation of site classification information will result in a more effective expenditure of money and effort; and 4) as site classification and intensive management progress, we will benefit from increased knowledge and understanding of the dynamics and function of forest ecosystems.

The extent to which our intensive management efforts and cash expenditures become good investments will depend in large part upon how well we understand the sites we are managing and to what degree we employ the site-specific treatments that will be increasingly required.

Table 1. Forest ecosystem productivity in relation to soil drainage and texture (Kabzems et al. 1986)

Forest ecosystem	Drainage[a]	Soil texture	Rotation age	Mean annual increment (m³/ha)	Yields (m³/ha) At rotation	Yields (m³/ha) At maturity
Pinus-Cladonia/Arctostaphylos	VR-R	Coarse	80	0.9	65	90
Picea glauca-Pleurozium	MW	Fine	70	4.5	315	455
Picea glauca/Populus-Cornus/Mitella	MW	Fine	65	4.3	285	330
Pinus/Picea mariana-Pleurozium	I	Mod. fine	75	1.6	120	140

[a] VR-R = very rapidly to rapidly drained; MW = moderately well drained; I = imperfectly drained.

[1] Personal communication, 1988, from J. Scheffer, Timber Management Branch, Alberta Forestry, Lands and Wildlife, Edmonton, Alberta.

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UNDERSTANDING THE UNDERSTORY: DILEMMA AND OPPORTUNITY

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INTRODUCTION

This paper focuses on the management of understory white spruce (*Picea glauca* (Moench) Voss.) in the Manitoba Lowlands Section (B.15), Boreal Mixedwood Section (B.18a), and Lower Foothills Section (B.19a) of Rowe (1972) (Fig. 1). These sections constitute over 130 000 km² of productive forest land, about one-third of the regional total. These lands are well-located with respect to transportation systems, communities, and power, so they can be readily exploited, managed, and protected. They are also among the most productive forest sites in the region, with gross mean annual increments of unmanaged stands commonly in the range of 2-6 m³/ha (Corns and Annas 1986; Kabzems et al. 1986).

With recent increased utilization of aspen (*Populus tremuoloides* (Michx.) in the region, these sites are becoming increasingly important as a source of commercial hardwoods in addition to their traditional role as a source of softwoods, especially white spruce. This situation poses new management challenges and presents new opportunities, particularly where both species occur together with white spruce as a high-value understory.

The long-term supply of commercial white spruce from mixedwoods can only be maintained or increased by successful establishment, growth, and protection of regeneration. In the intervening 60–80 years, white spruce supplies must come from existing stands, and any increases in supply must come from judicious management intervention in these stands.

This paper addresses costs, risks, and success in establishing and growing new white spruce plantations on mixedwood sites in the region to date and assesses the potential of understory stands as an interim source of white spruce growth and yield.

INVENTORY

Current Status and Future Needs

Current regional inventories of spruce-aspen mixedwoods are based on low intensity sampling and are unsuited as a source of detailed information on age, species mixture (especially aspen-poplar proportions) and the amount, size and distribution of white spruce understory.

Figure 2 shows the volume of wood currently inventoried in hardwood (H), mixedwood (HS, SH), and softwood (S) classes[1] in the region and clearly shows the relative importance of mixedwoods, particularly in Alberta.

The extent of the mixedwood resource tends to be underestimated because understories, particularly in H and HS stands, are not inventoried. Recent surveys in the region have found spruce understories in significant amounts in up to 80% of stands inventoried as H and HS, depending on fire and logging history and site and climate conditions. The amount of understory therefore merits serious consideration in white spruce management planning.

Until recently, white spruce understory was viewed somewhat like money in the bank on a long-term, low interest deposit with final yield to be realized after slow natural succession. In the future we may be increasingly faced with the situation of H and HS stands being scheduled for hardwood harvest, thereby jeopardizing understory spruce.

FUTURE WOOD SUPPLY

Role of Plantations

In the past, white spruce plantations on mixedwood sites have been established by both planting and seeding, usually following mechanical scarification of cutovers with substantial aspen residuals or by conversion of young aspen stands, mainly of fire origin, by mechanical clearing and planting. Costs of such work now ranges from $300 to $1000 per hectare for initial plantation establishment.

Recent literature reviews and surveys (Johnson and Gorman 1977; Johnson 1986; Drew 1987) and consultations with regional field staff indicate that while most

[1] H = 75%+ hardwood, HS = 51-75% hardwood, SH = 51-75% softwood, and S = 75%+ softwood.

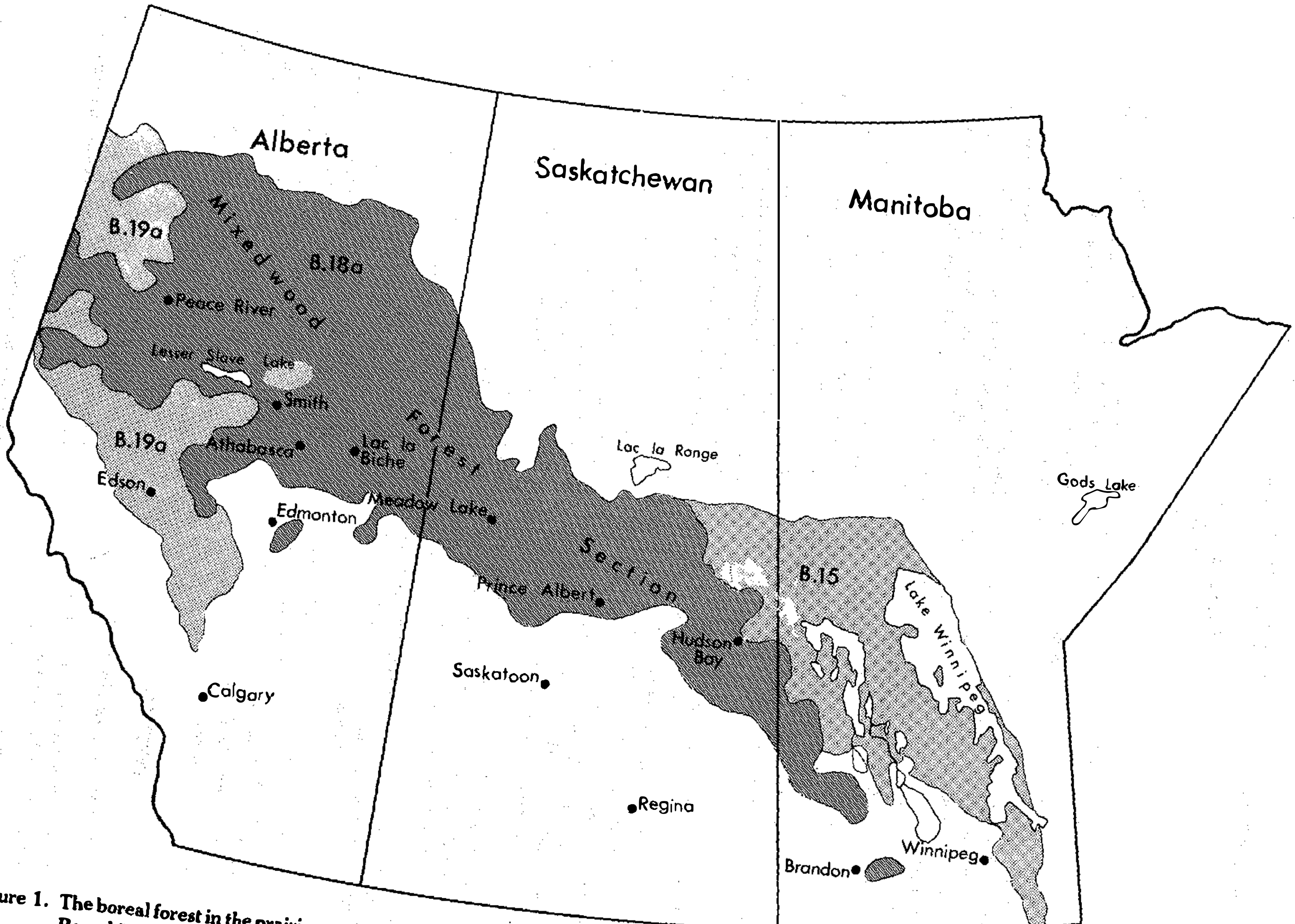

Figure 1. The boreal forest in the prairie provinces: sections B.15 (Manitoba Lowlands), B.18a (Mixedwood), and B.19a (Lower Foothills) of the Boreal Forest Region (Rowe 1972).

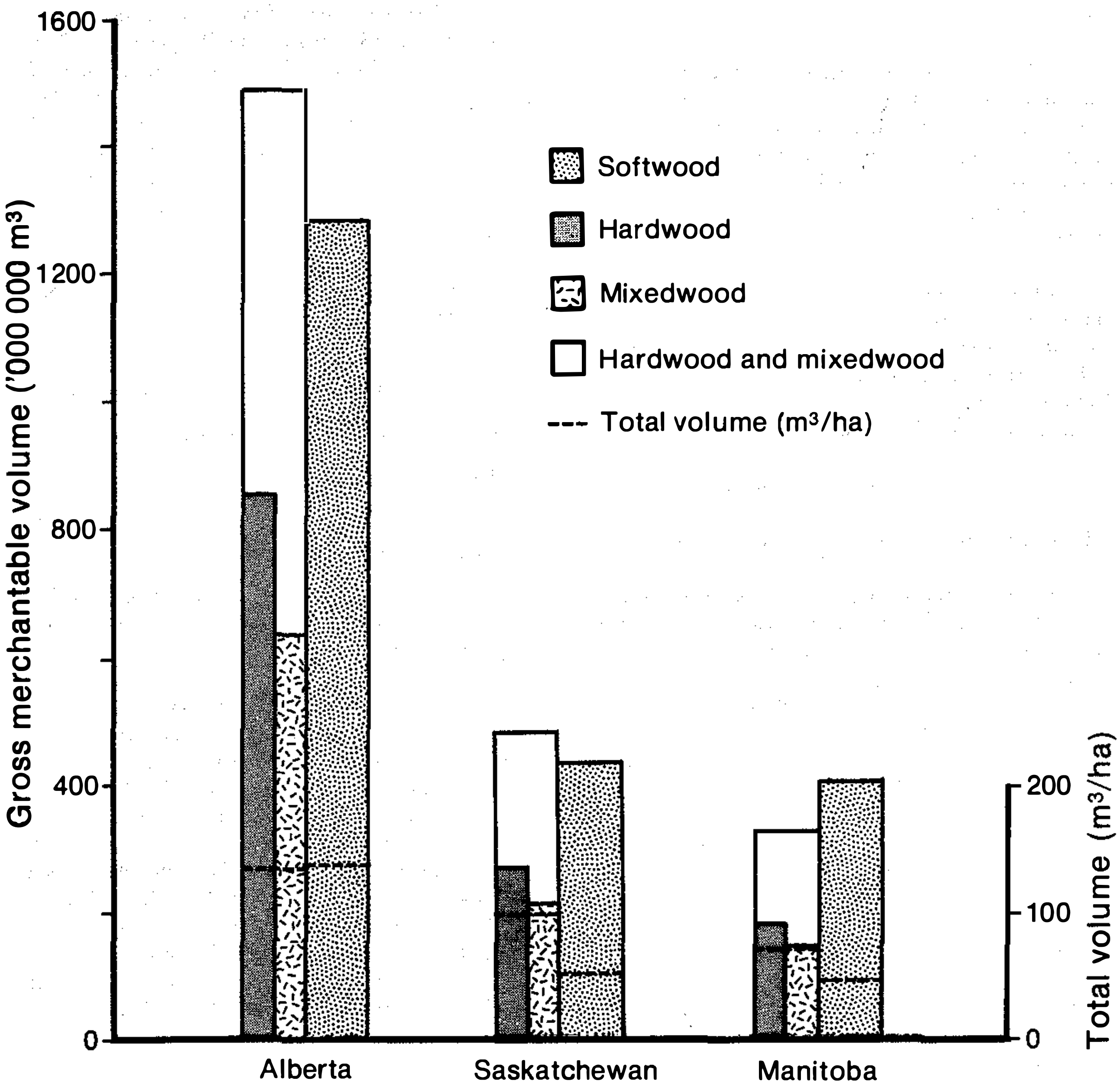

Figure 2. Gross merchantable timber volumes by major cover classes in Alberta, Saskatchewan, and Manitoba.

spruce plantations on mixedwood sites initially meet minimum stocking standards, they are tending to regress due to competition from brush and grass and damage by hares. The result is that up to two-thirds are reverting to mixedwood or hardwood status, with a subsequent loss in softwood growth potential. There is a critical need for effective tending of newly established plantations and no tools are available for achieving this economically. For example, recent reports on herbicide availability and outlook for Canada (Castrilli and Vigod 1987; Reynolds 1988) and for the world (Patosaari 1987) suggest that availability of such tools is unlikely to increase in the short term and that other means of competition control must be sought.

Success of spruce regeneration and tending on mixedwood sites may improve as utilization standards for all species increase and as markets develop for aspen and poplar. This will reduce the problems of heavy residual slash loads and standing residuals that are currently impediments to silviculture, but competition control measures will still be critical.

Given the costly, risky, and mainly unsuccessful history of white spruce regeneration on mixedwood sites to date, it seems that the future supply of commercial white spruce is dependent on existing sources, which are primarily understory stands occurring naturally in association with aspen and poplar.

Role of Understory Stands

A Tending and Harvesting Scenario

In an attempt to improve our understanding of understory management we developed a tending and harvesting scenario that assumes that both aspen and spruce will be grown on the same land base. Beginning with separate stand types rated HS and SH, we could harvest aspen under the following conditions: aspen overstories aged 60, 70, and 80 years; understory white spruce ranging from 40 to 50 years; and from 1200 to 2000 stems per hectare at 2.5 cm or greater diameter at breast beight (dbh). As well, all spruce over 25 cm dbh could be harvested, leaving a range of viable understory white spruce from 200 to 1000 stems per hectare and between 2.5 and 25 cm dbh. Sixty years later each stand could be harvested for all species and options for future management considered. Figure 3 illustrates the procedure.

This scenario does not necessarily imply a sustained yield policy for white spruce on the land base concerned. Its main function is to avoid waste by realizing the growth and yield potential of existing understory spruce in a given stocking range, while utilizing aspen. The subsequent issue of land base assignment, whether hardwood or softwood or possibly hardwood and softwood, in the next rotation is not addressed here. Of course, options other than aspen harvest may exist in cases where there is no aspen demand or where aspen is old or decadent or where white spruce has priority over aspen.

The feasibility of this scenario was assessed on the basis of field interviews with management foresters and by compiling sample plot data for aspen stands with spruce understories (MacLeod and Blythe 1953). Data from 38 plots were analyzed in groupings representing HS stands (51–75% aspen) and SH stands (51–75% white spruce) by hardwood age classes 60, 70, and 80 years, and the average number of understory white spruce stems was plotted for each of the six classes. A number of assumptions were then applied to determine a probable range of remaining viable residuals after the aspen were harvested. Assumptions included the following:

- all spruce over 25 cm dbh harvested to reduce windthrow;
- harvest everything over 25 cm dbh with 25% mortality caused by harvesting (Froning 1980);
- harvesting mortality of 25% as only loss;
- all spruce taller than 8 m blown down after harvest;
- all spruce over 8 m blown down and and 25% mortality caused by harvest;
- in all cases trees less than 3 m in height (2.5 cm dbh) are overgrown by aspen suckers following harvest (Johnson 1986).

The application of these assumptions to previously plotted diameter distributions of understory white spruce by age and stand type indicated that in each case, a range of viable residuals after harvest, from 200 to 1000 stems per hectare, was possible. If greater losses occurred (for example, from excessive logging damage or blowdown), this scenario would not apply. Diameter distribution curves were derived representing 200, 400, 600, 800, and 1000 viable residual white spruce and based on the shape of the average diameter distribution curve for each of the six stand type and age classes. Figure 4 illustrates the diameter distribution for HS stands with aspen aged 60 years.

This diameter distribution was the basis for subsequent growth and yield modeling.

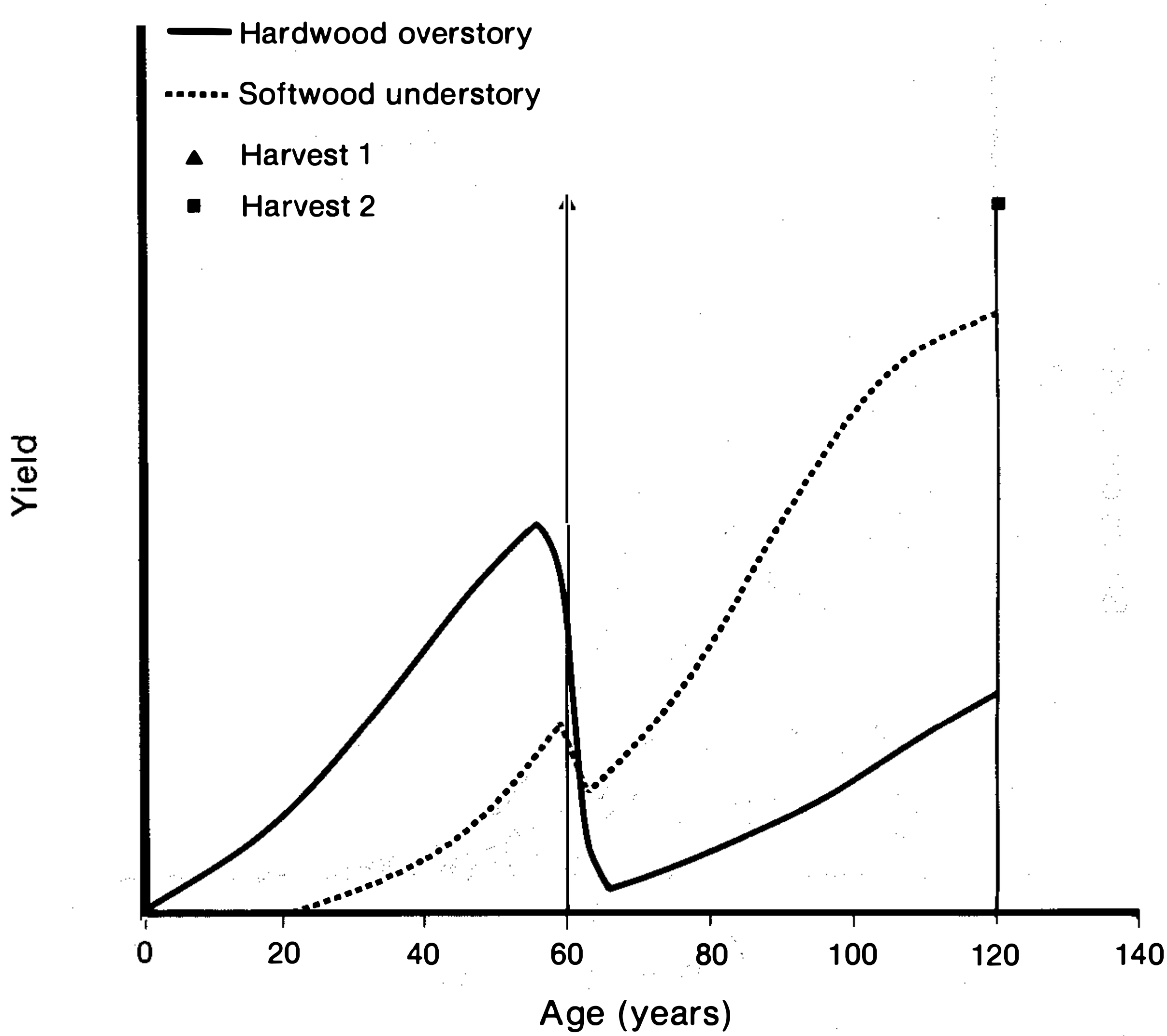

Figure 3. Generalized two-stage tending and harvesting scenario.

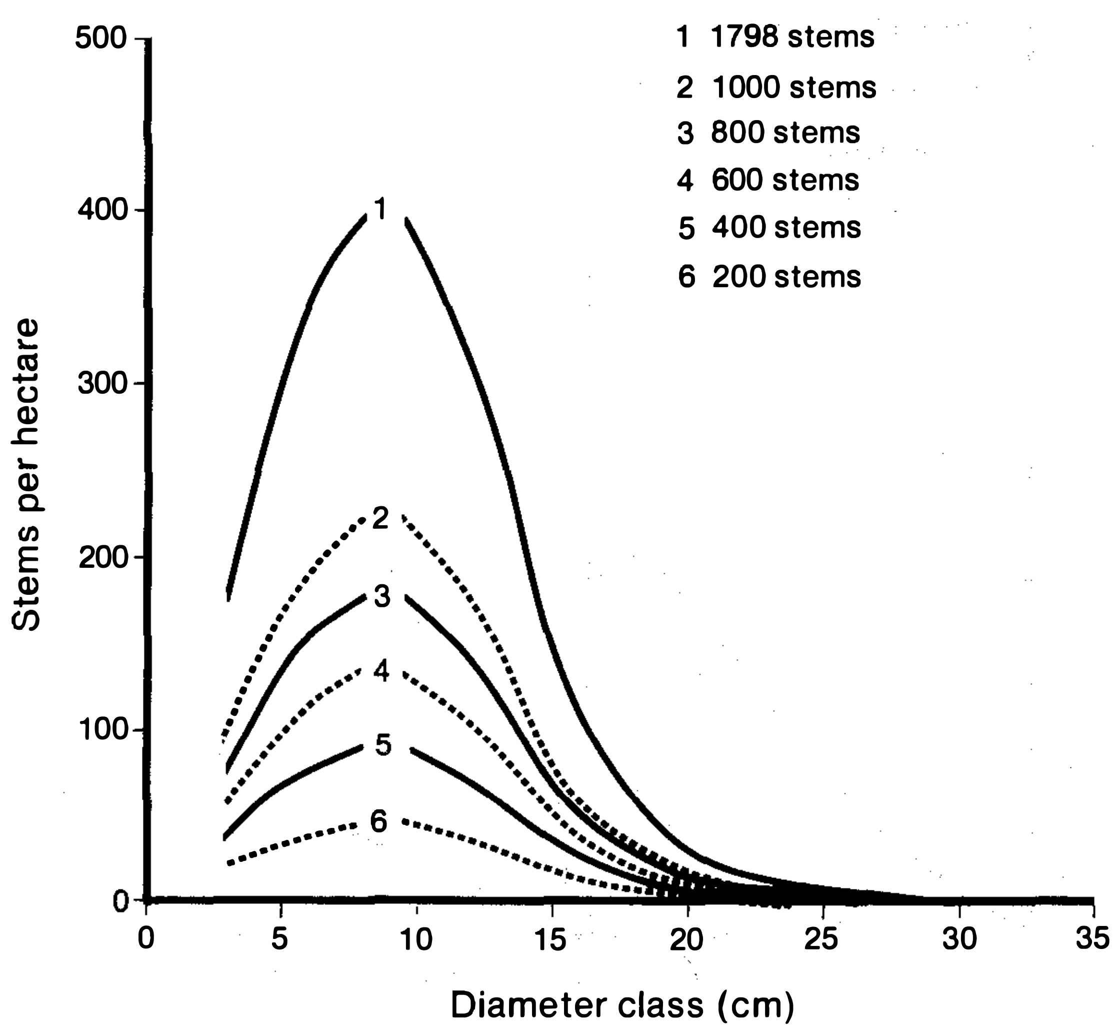

Figure 4. Diameter distribution curves for viable white spruce understory in HS stands (51–75% hardwood) with overstory aged 60 years.

Growth and Yield Projections

We used several in-house data sources as well as published information to derive yield estimates for residual spruce stands after the aspen component had been harvested.

We described initial conditions by dbh distributions (stand tables) and heights for each diameter class. The residuals we considered were between the 2.5-cm (1-in.) and the 23-cm (9-in.) dbh classes. We ignored trees smaller than the 2.5-cm class as they could be overtaken by aspen suckers; trees in the 25-cm (10-in.) dbh class and over were harvested. Figure 4 shows one such stand table with smoothed values.

We made the following assumptions in our growth and yield estimations:

- poplar as well as aspen were utilized;
- at the time of aspen harvest the average age of the spruce was 40 years;
- it took 5 years after the aspen harvest for the spruce to recover, for which period no increment was considered; after this period, fully released growth was applied;
- as there were unstocked areas after harvest, especially at lower spruce densities, aspen suckers filled in these openings to the extent shade tolerance would permit;
- the aspen understory following harvest had no significant impact on the growth of spruce understory;
- with crown closure of the dominant spruce, the aspen was crowded out;
- aspen yield, if any, was simply a complement of spruce yield that may be expected in mixed stands on similar sites in this region (Johnstone 1977).

We estimated the growth and yield of spruce with STEMS (Stand and Tree Evaluation and Modeling System), an individual tree distance independent growth model developed in the Lake States for species including white spruce (Belcher et al. 1982). We calibrated the model's performance to the point of crown closure using growth information of individually released spruce trees from a Canadian Forestry Service study established about 35 years ago in the Slave Lake Forest (Yang 1988).

We also ensured that our yield estimates thus obtained were reasonable in comparison with yields of white spruce plantations growing on sites of similar productivity (Berry 1987) and with yields of natural, fully stocked spruce-aspen stands in this region (Johnstone 1977).

Our yield forecasts with the STEMS model for medium-good productivity sites (Site Index = 24 m at reference age 70 years) for two mortality scenarios were for either no spruce mortality during the 40- to 100-year period or for increasing mortality rate with increasing stand density (Figs. 5 and 6; Table 1). Main results were as follows:

- maximum merchantable yield for spruce of about 550–590 m^3/ha at 100 years for the 600, 800, and 1000 trees/ha densities;
- predicted yield at 100 years about 10% lower for stands with 400 trees/ha and about 30% lower for stands with 200 trees/ha;
- for the two most dense stands (1000 and 800 trees/ha), final harvest 20 years earlier (at age 80) might give somewhat higher returns in terms of mean annual increment (MAI) but not necessarily in value increment;
- spruce mortality during the 60-year release period resulted in somewhat greater mean dbh for all stands. At higher densities where mortality was also greater, predicted yield was 5–10% lower than in stands without mortality. At the two lower densities—400 and 200 trees/ha—there was lower mortality and yield effects were negligible.

From these forecasts we may conclude that as few as 600 spruce trees/ha may ensure just about maximum merchantable volume yields at a 100-year rotation, and stands with 400 trees/ha can yield within 10% of the maximum yield. At densities below 400 trees/ha, loss in yield will accelerate. Some loss, as shown for 400 trees/ha may be acceptable, because saving fewer trees means reduced harvesting costs; whereas trying to save more than 300–400 trees/ha is likely to increase harvesting costs in an exponential fashion.

These forecasts showed negligible mortality impact on yield at higher densities. Trees in such stands fully occupy the area soon after harvest, and mortality among smaller trees would only ensure continued rapid growth of the remaining trees.

In addition to volume yield, other considerations such as knot size, proportion of juvenile wood, and specific gravity of the wood produced may also be important in developing treatment prescriptions for this

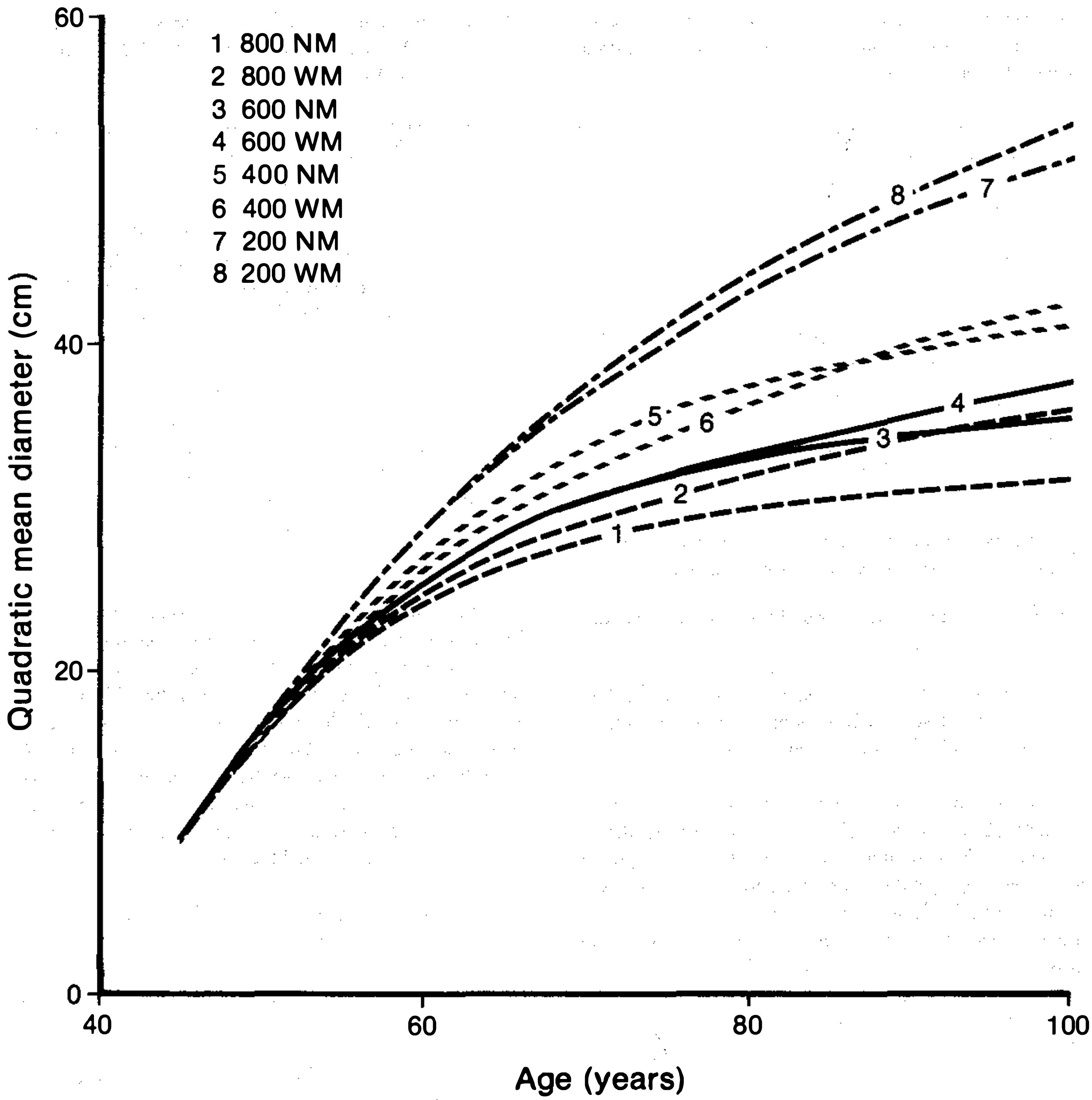

Figure 5. Quadratic mean diameter at breast height by age and density, with (WM) and without (NM) mortality.

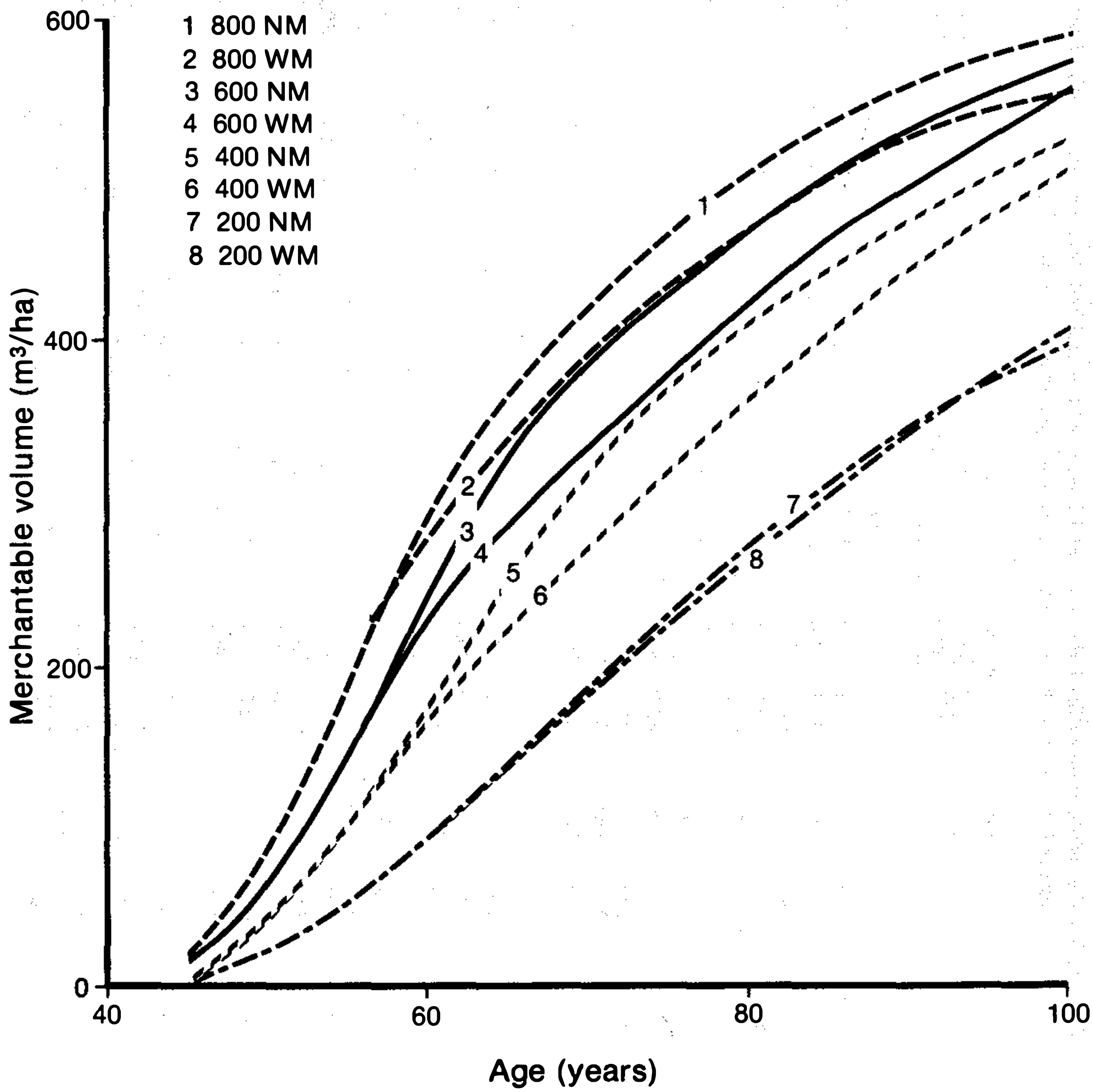

Figure 6. Merchantable volume by age and density, with (WM) and without (NM) mortality.

Table 1. Yield of white spruce (Site Index 24 m at 70 years) at five residual stand densities, with (WM) or without (NM) mortality during prediction period. Release was by harvesting poplar at spruce age 40 years

Age	Number of trees		Basal area (m²/ha)		Dbh[c] (cm)		Height[d] (m)		Total volume (m³/ha)		Merchantable volume (m³/ha)[e]		Mean annual increment (m³/ha)	
	NM[a]	WM[b]	NM	WM	NM	WM	NM	WM	NM	WM	NM	WM	NM	WM
45	1000	1000	7.7	7.7	9.9	9.9	7.5	7.5	33	33	24	24	0.5	0.5
50	1000	951	19.1	18.9	15.6	15.9	12.7	12.9	125	123	102	101	2.0	2.0
55	1000	898	32.1	31.0	20.2	20.9	16.7	17.0	255	244	222	212	4.0	3.9
60	1000	859	42.5	41.6	23.3	24.8	19.0	19.7	370	362	325	326	5.4	5.4
65	1000	818	48.5	46.4	24.8	26.9	20.2	20.9	439	419	392	375	6.0	5.8
70	1000	779	53.2	50.4	26.0	28.7	21.0	21.9	494	467	445	422	6.4	6.0
75	1000	741	56.9	53.4	26.9	30.3	21.6	22.6	538	505	488	460	6.5	6.1
80	1000	721	59.8	56.0	27.6	31.4	22.0	23.2	573	538	521	492	6.5	6.2
85	1000	700	62.0	57.9	28.1	32.5	22.3	23.6	599	562	546	516	6.4	6.1
90	1000	676	63.4	59.1	28.4	33.4	22.6	23.9	617	578	563	533	6.3	5.9
95	1000	651	64.2	59.7	28.6	34.2	22.7	24.1	626	588	573	543	6.0	5.7
100	1000	625	64.3	59.9	28.6	34.9	22.7	24.3	627	593	574	548	5.7	5.5
45	800	800	6.2	6.2	9.9	9.9	7.3	7.3	26	26	19	19	0.4	0.4
50	800	774	15.7	15.6	15.8	16.0	12.5	12.6	101	100	83	82	1.7	1.6
55	800	746	27.0	26.4	20.7	21.2	16.5	16.8	212	206	185	180	3.4	3.3
60	800	728	38.0	36.5	24.6	25.3	19.4	19.5	333	317	296	281	4.9	4.7
65	800	709	44.2	41.6	26.5	27.3	20.6	20.8	403	375	366	338	5.6	5.2
70	800	691	49.1	46.1	27.9	29.2	21.5	21.7	460	428	421	389	6.0	5.6
75	800	673	53.0	50.0	29.0	30.8	22.2	22.5	507	474	466	434	6.2	5.8
80	800	654	56.2	53.2	29.9	32.2	22.7	23.2	545	513	503	472	6.3	5.9
85	800	635	58.8	55.7	30.6	33.4	23.1	23.7	577	545	533	504	6.3	5.9
90	800	615	60.9	57.5	31.1	34.5	23.3	24.1	602	568	557	527	6.2	5.9
95	800	593	62.5	58.7	31.5	35.5	23.6	24.4	621	584	576	543	6.1	5.7
100	800	570	63.6	59.3	31.8	36.4	23.7	24.6	634	593	588	552	5.9	5.5
45	600	600	4.6	4.6	9.9	9.9	7.0	7.0	19	19	13	13	0.3	0.3
50	600	590	12.1	12.1	16.0	16.2	12.2	12.3	76	75	62	62	1.2	1.2
55	600	579	21.4	21.2	21.3	21.6	16.3	16.4	165	163	142	140	2.6	2.5
60	600	566	30.9	30.2	25.6	26.1	19.2	19.3	266	259	240	234	4.0	3.9
65	600	551	39.1	34.9	28.8	28.4	21.1	20.6	360	313	330	285	5.1	4.4
70	600	546	44.0	39.3	30.6	30.3	22.0	21.6	416	363	385	334	5.5	4.8

75	600	542	48.0	43.4	31.9	31.9	22.8	22.4	464	410	431	379	5.7	5.1
80	600	537	51.4	47.0	33.0	33.4	23.3	23.1	504	454	469	421	5.9	5.3
85	600	533	54.2	50.6	33.9	34.8	23.7	23.7	538	495	502	462	5.9	5.4
90	600	528	56.6	53.6	34.7	36.0	24.1	24.2	567	532	530	497	5.9	5.5
95	600	523	58.7	56.2	35.3	37.0	24.3	24.6	591	564	553	528	5.8	5.6
100	600	518	60.3	58.4	35.8	37.9	24.6	24.9	611	590	573	553	5.7	5.5
45	400	400	3.1	3.1	9.9	9.9	6.6	6.6	12	12	9	9	0.2	0.2
50	400	398	8.4	8.4	16.3	16.4	11.7	11.7	50	50	41	41	0.8	0.8
55	400	396	15.3	15.2	22.1	22.1	15.8	15.9	114	113	99	99	1.8	1.8
60	400	393	22.6	22.5	26.9	27.0	18.8	18.8	190	189	173	172	2.9	2.9
65	400	390	29.8	27.4	30.8	29.9	20.9	20.3	269	242	249	223	3.8	3.4
70	400	387	36.5	32.0	34.1	32.5	22.4	21.5	345	294	322	273	4.6	3.9
75	400	383	41.3	36.3	36.2	34.7	23.3	22.5	400	343	376	321	5.0	4.3
80	400	380	44.6	40.3	37.7	36.7	23.8	23.3	439	390	413	365	5.2	4.6
85	400	377	47.4	43.9	38.9	38.5	24.3	23.9	473	432	446	407	5.2	4.8
90	400	374	49.9	47.2	39.9	40.1	24.7	24.5	503	472	474	444	5.3	4.9
95	400	371	52.1	50.2	40.8	41.5	25.0	24.9	529	507	500	478	5.3	5.0
100	400	368	54.1	52.8	41.5	42.8	25.2	25.3	553	538	522	509	5.2	5.1
45	200	200	1.5	1.5	9.9	9.9	6.1	6.1	6	6	4	4	0.1	0.1
50	200	199	4.4	4.4	16.7	16.7	10.9	10.9	24	24	19	19	0.4	0.4
55	200	198	8.4	8.4	23.1	23.2	14.9	14.9	59	58	52	52	0.9	0.9
60	200	197	12.9	12.8	28.7	28.8	17.8	17.8	103	102	94	94	1.6	1.6
65	200	196	17.5	17.4	33.4	33.6	19.9	19.9	150	149	140	139	2.2	2.1
70	200	195	22.0	21.7	37.4	37.7	21.4	21.4	199	196	187	184	2.7	2.6
75	200	194	26.3	25.9	40.9	41.2	22.5	22.5	246	241	231	227	3.1	3.0
80	200	192	30.3	29.7	43.9	44.4	23.4	23.4	291	284	274	268	3.4	3.3
85	200	191	34.0	33.3	46.6	47.1	24.1	24.1	333	325	315	307	3.7	3.6
90	200	190	37.5	36.6	48.9	49.5	24.7	24.6	373	362	353	343	3.9	3.8
95	200	188	39.8	39.6	50.4	51.7	25.0	25.1	400	397	379	376	4.0	4.0
100	200	187	41.7	42.3	51.6	53.7	25.3	25.5	422	429	400	407	4.0	4.1

[a] No mortality during the prediction period.
[b] Mortality proportion to stand density during the period.
[c] Quadratic mean dbh (diameter at breast height).
[d] Lorey's height.
[e] 9 cm diameter at breast height outside bark; 7.6 cm top diameter inside bark; 15.2 cm stump.

cover class. Some of these factors may suggest higher densities than would be optimum on the basis of MAI, so these factors would have to be simultaneously considered in crop planning for specific stands.

We also need to note that these forecasts assumed a fairly regular distribution of spruce trees on the area. Clumping of spruce would result in reduced yield for this species in proportion to the degree of clumping. Open patches, however, would be utilized by aspen and poplar and thus would contribute to total yield on the area.

Johnstone (1977) in his mixedwood tables presents total stem volume yield (i.e., spruce and aspen-poplar), of just under 450 m^3/ha for stands growing on similar sites. In the 10 scenarios for which we forecasted yield with STEMS, only the low-density scenario (i.e., 200 trees/ha, with and without mortality) produced under 450 m^3/ha of spruce at age 100 years. The shortfall was about 40 m^3/ha. As we suggested earlier, this shortfall in spruce yield should be made up by aspen and poplar.

Advantages and Disadvantages for Tending and Harvesting Scenario

Successful execution of the tending and harvesting scenario would achieve substantial spruce yields in a shorter time and without the costs and risks associated with establishing and growing new plantations with present technology. It also provides for an aspen harvest.

Disadvantages include problems with adapting current harvesting equipment to protect sufficient understory white spruce adequately enough to produce a crop. There are also potential problems with windthrow on exposed and moist to wet sites, and leader weevilling and loss may prove to be a problem as well. In areas with no demand for aspen and where white spruce has a priority, other scenarios for understory white spruce release not entailing problems of harvest technology and other associated risks to the understory should be considered in order to realize the growth and yield potential of spruce.

Replacement Cost of Spruce Understories

In order to estimate the value of understory stands such as those previously discussed, we assumed a mixedwood site of good productivity (Site Index 21 m at age 70; MacLeod and Blythe 1953) with an aspen-poplar residual density of 50–150 m^3/ha after softwood harvest, assigned it to the coniferous land base, and regenerated it to the prescriptions outlined in Table 2.

For each of the options, growth assumptions were made and applied to Figure 7 as follows:

- the guide curve is from MacLeod and Blythe (1953) for Site Index 21 m at 70 years;
- plantations in Prescription 1 (released) were assumed to require 10 years to reach 2 m, after which they grew freely, following the growth trajectory for HS stands with aspen age 60 years (Fig. 6), until reaching a mean height previously determined for each combination of stand type and age. The time required to reach mean height was the reference age to which prescription costs were compounded;
- plantations in Prescription 2 (no release) were assumed to require 10 years to reach 1 m and continued at the same growth rate until they reached 3 m, when they became free-growing and followed the trajectory in Figure 7, with the time derived for compounded cost derivations as discussed for Prescription 1.

The result of the above analysis for each of the six natural stand type and age combinations was a cost per hectare (Table 3). Replacement costs were substantial, as illustrated for HS stands with aspen age 60; at 4% interest, the released stands cost over $4200/ha and unreleased stands were over $6600/ha. Even at 3% interest the costs were about $3000/ha and $4000/ha for released and unreleased stands, respectively.

Table 4 shows replacement costs in terms of cost per metre of stem and cost per tree. By assigning appropriate survival rates to the 1800 planted original trees and generating a range of understory stocking from 200 to 1000 stems/ha, obtaining aggregate and average heights from number of trees, and then dividing total compounded costs by aggregate height and by number of stems, cost per metre and cost per tree, respectively, were derived (Ball 1980). Results are illustrated further in Figures 8 and 9. Cost per metre and cost per tree rise dramatically as stocking levels decline.

Costs derived here are used to illustrate understory value and consequences of plantation failure, assuming a priority on white spruce regeneration. Actual costs and values for such replacement stands can only be determined from product and market conditions for specific situations and are beyond the scope of this report.

SUMMARY AND CONCLUSIONS

1) Mixedwoods are a large and productive source of forest products in this region. They have historically been primarily a source of softwood, especially white spruce, with little demand for their hardwood components. This situation is now changing, with increasing demand for aspen. This situation poses new

Table 2. Prescription costs for white spruce regeneration with and without aerial release

Year	Option	Cost/ha ($)
Prescription 1		
0	Mechanical site preparation	230.00
1	Planting—1800 bareroot stock at 33.8¢/tree	608.00
4	Regeneration survey	16.45
5	Aerial release of Vision at 5 L/ha	150.00
Total		1004.45
Prescription 2		
As above but not released		854.45

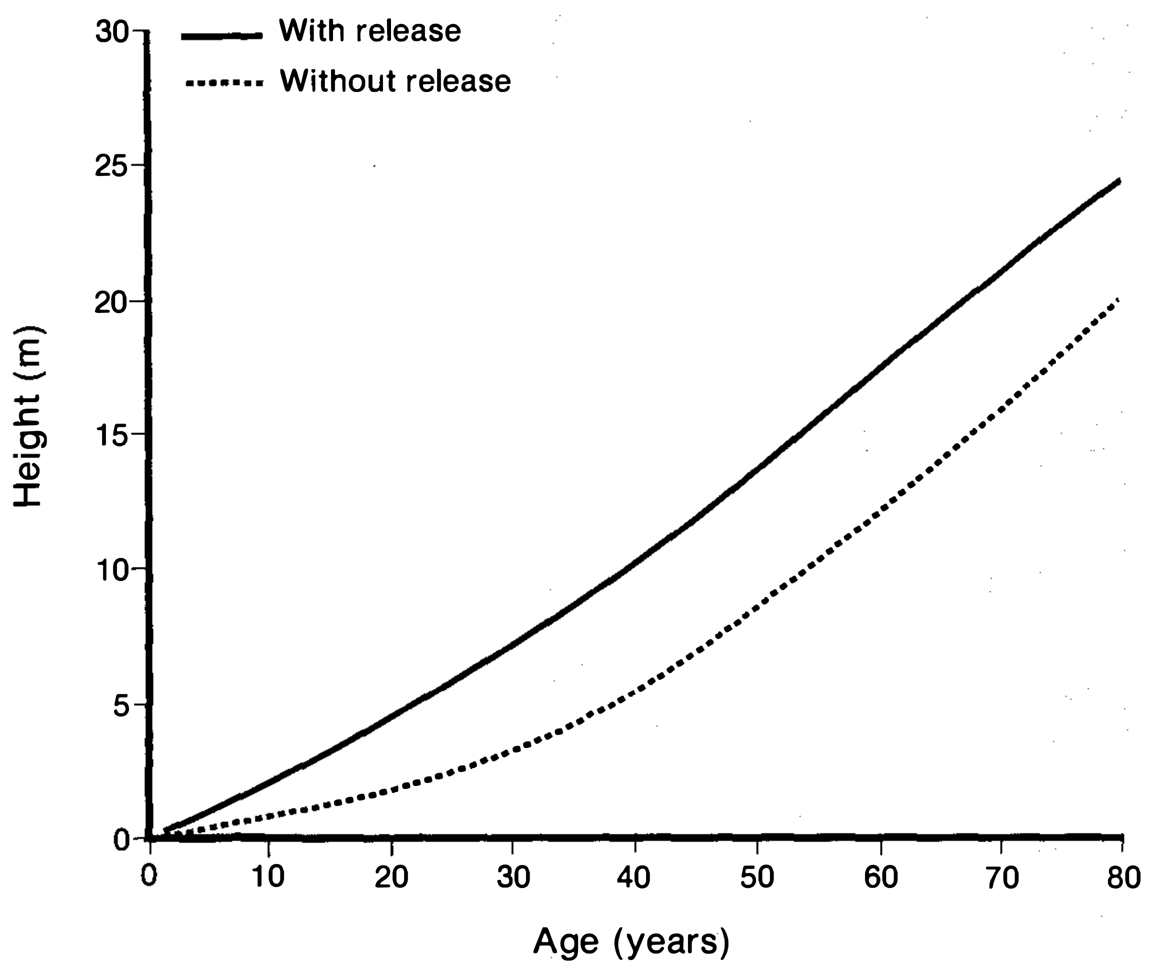

Figure 7. Predicted growth of white spruce regeneration on a good mixedwood site, with and without competition control.

Table 3. Replacement costs at varying interest rates for white spruce stands regenerated with and without release treatment

Stand type[a]	Overstory age (yr)	Mean height (m)[b]	Years to mean height: Release	Years to mean height: No release	Replacement value for released stand ($/ha): 3%	4%	5%	6%	Replacement value for unreleased stand ($/ha): 3%	4%	5%	6%
HS	60	9.22	37	52	2 965	4 226	6 003	8 502	4 000	6 624	10 920	17 915
HS	70	10.58	42	56	3 437	5 141	7 662	11 377	4 502	7 750	12 273	22 618
HS	80	11.01	43	57	3 540	5 347	8 045	12 060	4 637	8 060	12 937	23 975
SH	60	11.54	45	58	3 756	5 783	8 869	13 550	4 776	8 382	14 633	25 413
SH	70	11.00	43	57	3 540	5 347	8 045	12 060	4 037	8 060	13 937	23 975
SH	80	12.15	47	60	3 985	6 255	9 778	15 225	5 067	9 066	16 133	28 555

[a] HS = 51–75% hardwood; SH = 51–75% softwood.

[b] Mean height of understory white spruce derived from the analysis of HS and SH plots with overstory ages of 60, 70, and 80 years.

Table 4. Cost per metre and cost per tree for stand replacement at 4% interest

	Release					No release				
Average height (m)	9.22					9.22				
Years to average height	37					52				
Replacement value ($/ha)	4226					6624				
Trees per hectare	1000	800	600	400	200	1000	800	600	400	200
Survival (%)[a]	56	44	33	22	11	56	44	33	22	11
Aggregate height (m)[b,c]	9220	7376	5532	3688	1844	9220	7376	5532	3688	1844
Value ($/m)	0.46	0.57	0.76	1.15	2.29	0.72	0.90	1.20	1.80	3.59
Value ($/tree)	4.23	5.28	7.04	10.56	21.13	6.62	8.28	11.04	16.56	33.12

[a] Survival rates applied to original 1800 planted trees to obtain appropriate stocking levels in table.
[b] Number of trees per hectare times average height.
[c] Competition technique from Ball (1980).

management challenges and presents new opportunities, particularly where aspen and spruce are grown and harvested on the same land base.

2) White spruce occur in substantial amounts as understories, particularly in stands currently inventoried H and HS, but current inventories do not document their amount, size, or distribution. As these stands are increasingly being scheduled for aspen harvest, information about the understory component becomes more critical to spruce management planning.

3) White spruce plantations on mixedwood sites in the region have proven expensive, risky, and generally unsuccessful to date, with up to two-thirds reverting to a mixedwood or hardwood status. Unless this situation can be changed, future supplies of white spruce must come mainly from established natural sources, primarily understory stands.

4) This report describes a tending and harvesting scenario that assumes a demand for aspen and has aspen and white spruce grown on the same land base. It is designed to protect existing white spruce understory, leaving a range of viable crop trees during the first cut, then harvesting both hardwoods and spruce in the final cut. If such a procedure proves practical, growth and yield rewards would be substantial and could supplement spruce production losses due to past plantation failures and assist in adjusting for imbalances in middle age classes in white spruce.

5) Harvest technology and crews currently employed may not be capable of providing adequate protection for white spruce understory stands. Under present circumstances, operators are being asked to absorb substantial production penalties and costs now to protect the understory in order to create added stand value 50-60 years in the future. It may be necessary to examine new approaches if future white spruce supplies are a priority issue in understory stands being scheduled for hardwood harvest. This may include specialized equipment and trained crews—possibly silviculture contractors—and may merit financial incentives.

6) Effective understory management planning requires more than improved mixedwood inventory. Because released understory stands may suffer losses due to windthrow on exposed slopes or in moist to wet sites and due to stem weevilling in some areas, a site description technique that incorporates these risk

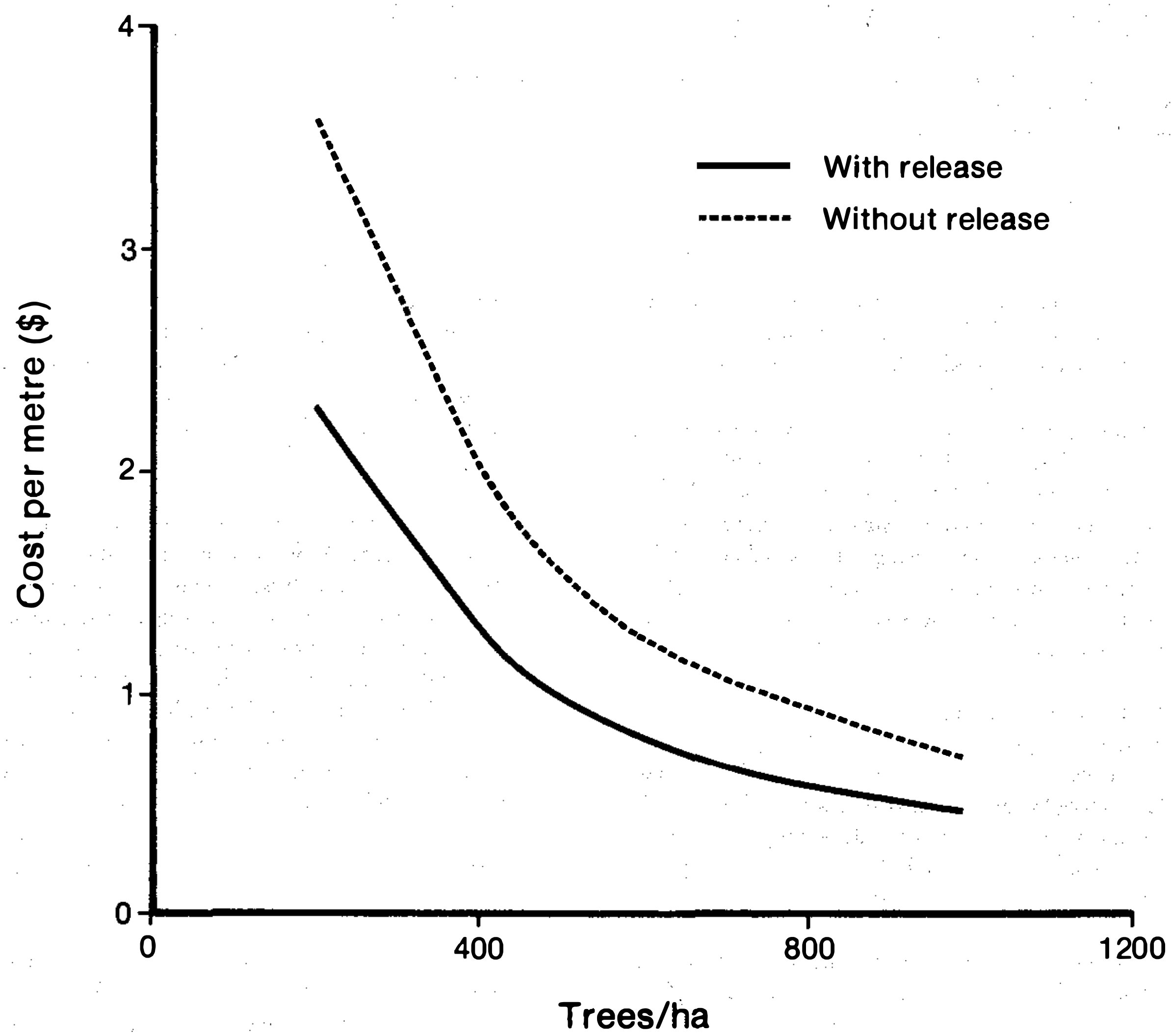

Figure 8. Cost per metre of aggregate height at 4% interest rate for white spruce regeneration for HS stand (51-75% hardwood) of aspen aged 60 years.

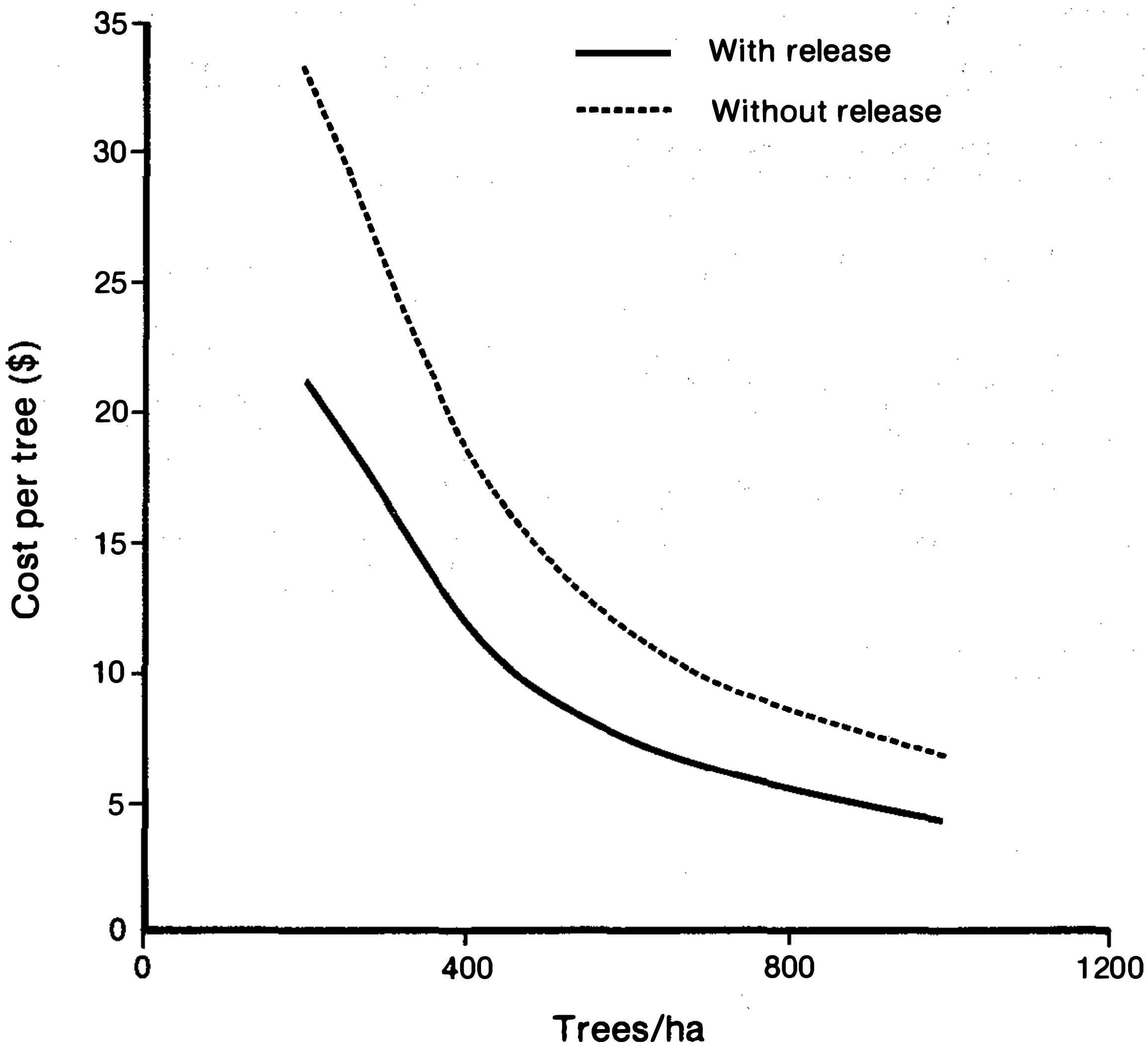

Figure 9. Cost per tree at 4% interest rate for white spruce regeneration for HS stand (51–75% hardwood) of aspen aged 60 years.

factors, along with growth and yield forecasts, is needed as a guide to management prescriptions.

7) In cases where spruce production has a priority, and where understory stands exist, a variety of options for release and protection of these stands should be developed in view of their growth and yield potential.

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DEVELOPMENT OF CROP PLANS FOR HARDWOOD AND CONIFER STANDS ON BOREAL MIXEDWOOD SITES

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INTRODUCTION

The boreal mixedwood forest is a complex and enigmatic component of the boreal forest (Rowe 1972). According to Rowe, mixedwoods are common in almost all sections of the Boreal Forest Region except in the lowlands south and east of Hudson's Bay. As Rowe's descriptions of the composition of mixedwoods in the boreal forest are varied, let us first examine his definition of the Boreal Forest Region (Rowe 1972).

> Although the forests are primarily coniferous, there is a general admixture of broadleaved trees such as white birch and its varieties, trembling aspen and balsam poplar; the latter two species playing an important part in the central and south-central portions, particularly in the zone of transition to the prairie.

The dynamic nature of boreal mixedwood is not included in the above definition, nor is it included in Rowe's (1972) definition of the B.18a Mixedwood Section, which is the primary concern of this paper. That definition is as follows:

> The characteristic forest association of the well-drained uplands is, as the name implies, a mixture in varying proportions of trembling aspen and balsam poplar, white and Alaska birches, white spruce and balsam fir, the last two species especially prominent in old stands. The cover type of greatest areal extent is the trembling aspen, a result of the ability of this species to regenerate readily following disturbance. In addition to its usual dominance on sandy areas, jack pine enters into the forest composition on the drier till soils, and mixes with black spruce on the plateau-like tops of the higher hills. Lower positions and the upper water-catchment areas develop black spruce and tamarack muskeg in which, however, the accumulation of peat is not deep. There is a minor occurrence of white elm, green ash, Manitoba maple and burr oak along the edges of the Section, noticeably in the southeast.

The above definition does not pay sufficient attention to the dynamic nature of the boreal mixedwood forest. It does not describe it as a stratified mixture that originates after wildfire with well-defined successional behavior, although it does state that "white spruce and balsam fir" are "especially prominent in old stands".

The key to understanding the ecology of boreal mixedwood stands and developing effective crop plans (Day 1985, 1987, 1988) for its management is to study its fire history, the autecology of its component species, the nature of the dynamic changes that take place during forest succession, and their relationship to growth and yield.

Day (1981) described the dynamic nature of boreal mixedwood in Ontario. He showed that natural boreal mixedwood there invariably originates after wildfire, tends to have a fire rotation of 75±50 years, and is composed of pioneer, midsuccessional, and late successional species arranged in three distinct canopy layers. He described the layered structure of boreal mixedwood as follows.

Upper Layer: Composed of varying proportions of aspen, paper birch, and jack pine that are intolerant pioneer species, reproduce dependably, abundantly, and vigorously from suckers and sprouts or from seed after wildfire, and are initially very fast growing so that they dominate the species in the subordinate layers.

Middle Layer: Composed of white spruce and black spruce that are moderately tolerant pioneer species, reproduce less dependably from seed after wildfire, and are initially slow-growing and frost-susceptible (black spruce less than white spruce) and invariably are dominated by the species in the upper layer.

Lower Layer: Composed of balsam fir, hazel, and mountain maple (and other hardwoods) that are very tolerant, late successional species, reproduce with difficulty immediately after wildfire, and are initially slow in colonizing the burn and are invariably suppressed by the species in the superior layers.

Aspen is often thought to be the most productive species in natural stands on the better sites in boreal mixedwood (Plonski 1981) because it invaribly dominates the upper canopy of natural fire-origin stands (Day 1981). There is now considerable evidence that coniferous species, particularly white spruce, may be far more productive than aspen in managed stands on such sites, provided they are established at an optimum initial spacing and that aspen competition is controlled.

The objectives of this paper are

1) to question the superior productivity of aspen in boreal mixedwood and to show that crops of conifers, particularly white spruce, can be grown to advantage; and

2) to develop sample crop plans for white spruce and aspen stands on the better sites in the boreal mixedwood.

GROWTH AND YIELD OF THE B.18a MIXEDWOOD

The growth and yield of natural forest in the B.18a Mixedwood Section (Rowe 1972) have been reported on by Kirby (1962), Kabzems (1971), and Johnstone (1977). These authors show that aspen dominates for approximately 60 years and then is replaced by white spruce, which develops much greater volume per hectare than aspen.

Figure 1 shows the volume per hectare over age of a Site Index 22.5 mixedwood forest in the B.18a Mixedwood Section as given in Johnstone's (1977) yield tables. Aspen produces *75% of its maximum volume by age 20* and the total maximum volume of 167 m^3/ha at age 70. The volume per hectare of aspen then declines to 155.1 m^3/ha, or 72% of the maximum, by age 100. *White spruce produces slightly more volume per hectare than aspen at age 65 and 275.3 m^3/ha, or 177% more, at 100 years.*

Figure 2 shows basal area per hectare over age of a) a Site $Index_{50}$ 22.5 natural mixedwood forest and b) Site $Index_{50}$ 23.5 Norway spruce plantations grown in the United Kingdom. The basal area per hectare curve for white spruce is taken directly from Johnstone's (1977) yield table; that for aspen was derived from Johnstone's volume per hectare data by dividing by a tree of mean volume from Plonski (1981) and estimating the basal area per hectare. *Aspen in the mixedwood reaches a maximum basal area of 22.2 m^2/ha at age 20 and then declines to 12.4 m^2/ha, or 56% of the maximum, at age 100.* In contrast, white spruce only develops 3.7 m^2/ha basal area by age 20 (16.7% of aspen's) but develops 34.0 m^2/ha basal area at age 100 (273% of aspen's).

Figure 2 also shows the basal area per hectare of a pure, optimally managed and thinned Site $Index_{50}$ 23.5 Norway spruce stand in the United Kingdom (Hamilton and Christie 1971; Edwards and Christie 1981) for comparison. Although the comparison between white spruce in the B.18a Mixedwood Section and Norway spruce in the U.K. is approximate, it shows the very high standing basal areas that can be produced in well-managed spruce stands. The basal area of the managed Norway spruce after thinning rises from 22 to 46 m^2/ha from 20 to 80 years and is equal to or better than that of spruce and aspen combined in the B.18a Mixedwood Section; before thinning it is much higher and rises from 30 to 55 m^2/ha over the same period.

Figure 3 shows the basal area per hectare over age of the white spruce component of natural Site $Index_{50}$ 12.5 to 25.0 mixedwood stands in the B.18a Mixedwood Section (Johnstone 1977). It clearly shows the poor development of basal area per hectare of this species after age 60 in the more productive Site $Index_{50}$ 17.5 to 25.0 stands. Such poor development in the better stands can only be the result of competition from the aspen, which grows poorly after age 60 (Figs. 1 and 2).

Figure 4 compares the basal area per hectare over age of the white spruce component of natural Site $Index_{50}$ 15 white spruce-aspen stands in the B.18a Mixedwood Section (Johnstone 1977) with pure white spruce planted in spacing trials at the Petawawa National Forestry Institute (Steill 1976). The comparison again clearly shows the very poor development of basal area per hectare of the white spruce component of the B.18a Mixedwood Section.

Figures 1 to 4 emphasize the negative effect of aspen on the growth of white spruce in the boreal mixedwood. They clearly show the slow early growth of white spruce when it is overtopped and dominated by aspen and the low productivity of aspen relative to white spruce after age 60. When the performance of white spruce in the B.18a Mixedwood Section is compared to that of white spruce (or Norway spruce) in pure plantations, it can only be rated as dismally low. These results clearly indicate that a new approach must be taken in managing boreal mixedwood.

CROP PLANS FOR SPRUCE AND ASPEN IN THE BOREAL MIXEDWOOD FOREST

Crop plans (Day 1985, 1987, 1988) are based on density models developed from an understanding of

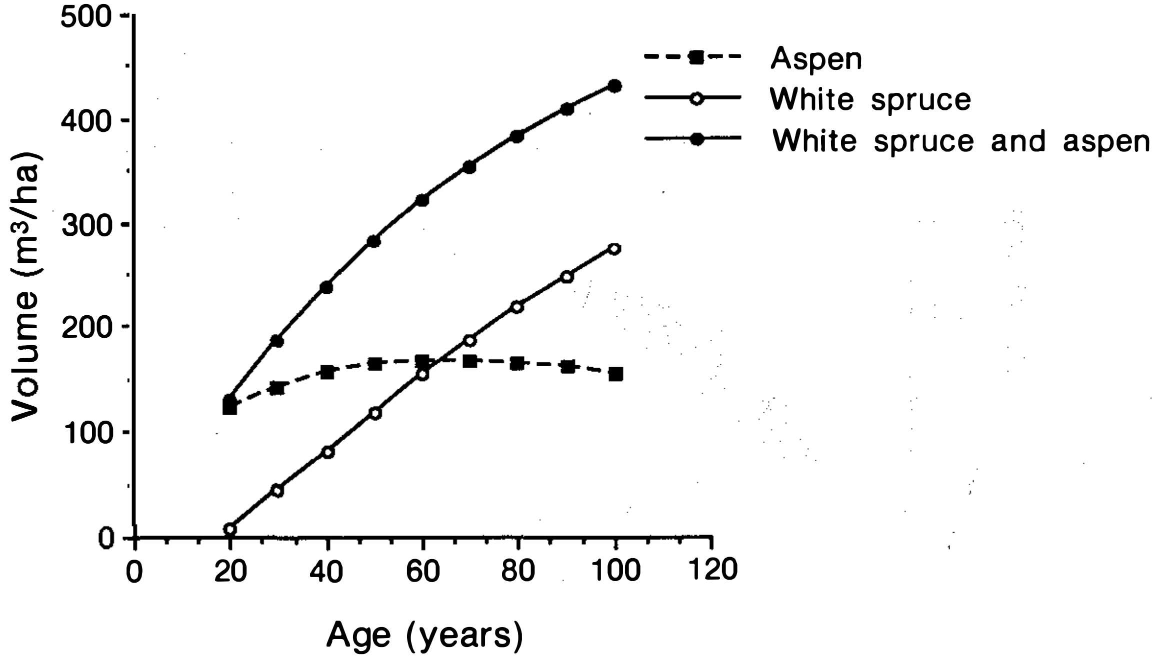

Figure 1. Stand volume over age for Site Index 22.5 aspen and white spruce (Johnstone 1977).

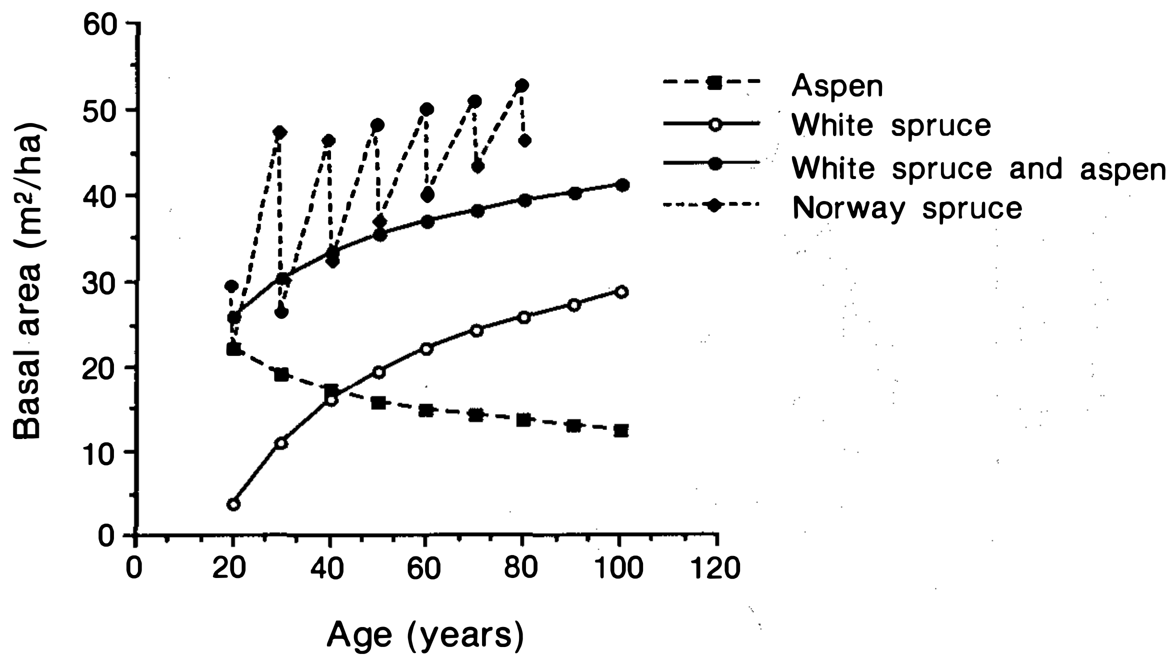

Figure 2. Stand volume over age for Site Index 22.5 naturally occurring aspen and white spruce and Site Index 23.5 planted Norway spruce.

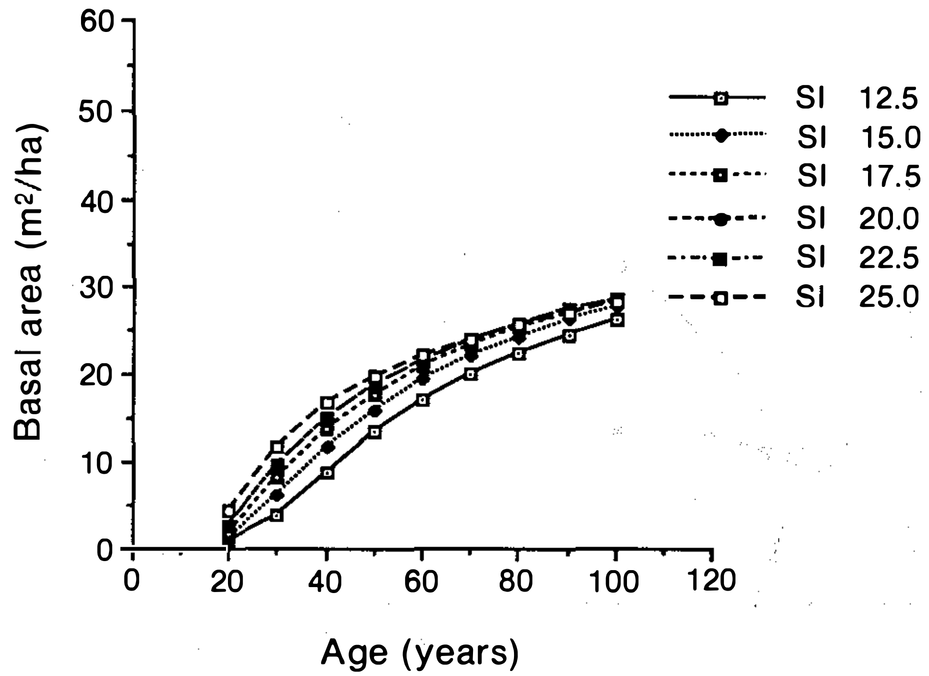

Figure 3. Stand volume over age for naturally occurring white spruce (Johnstone 1977).

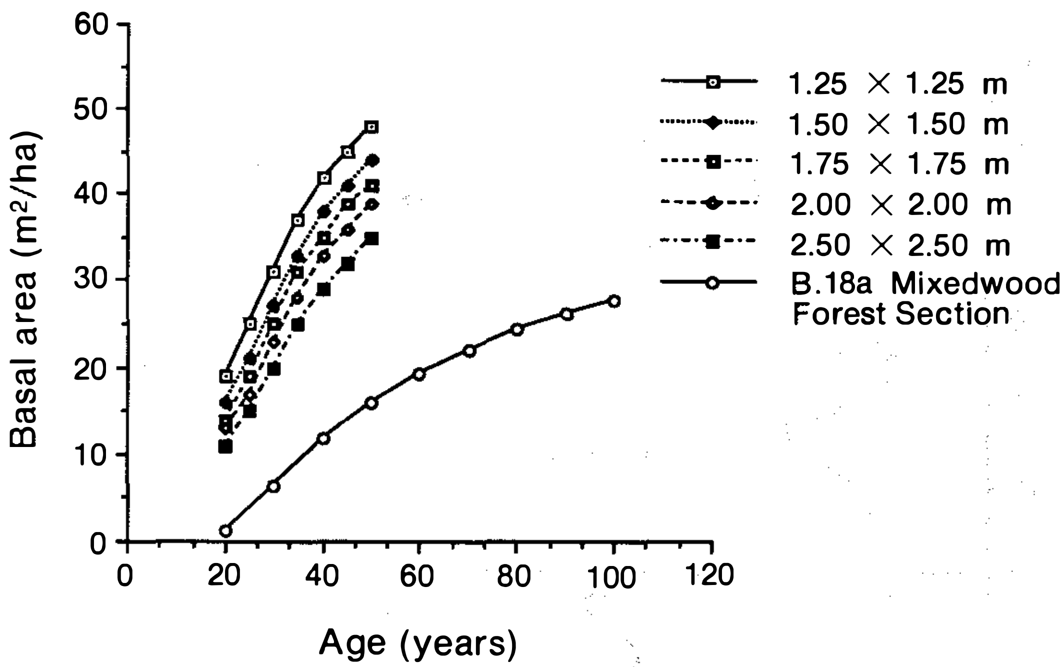

Figure 4. Stand volume over age for Site Index 15 white spruce planted at the Petawawa National Forestry Institute (Stiell and Berry 1973) and occurring naturally in the B.18a Mixedwood Section (Johnstone 1977).

species behavior in relation to the laws of self-thinning defined by the 3/2 Rule (Yoda et al. 1963; Drew and Flewelling 1977). In this paper, Spacing Factor percentage (SF%) and Reineke's Stand Density Index (RSDI) are used to define satisfactory density ranges for growing white spruce and aspen as pure even-aged crops. Day (1985) provides details of the crop planning method.

Tables 1 to 3, which are derived from Johnstone (1977), present the preliminary data needed for the development of crop plans for pure crops of white spruce or aspen in the B.18a Mixedwood Section. Table 1 shows that natural mixedwood is very dense and is probably subject to both severe inter-and intraspecific competition. The SF% and RSDIs given in Table 4 range from 9.4 and 3447 at 20 years to 11.0 and 3484 at 100 years. *Such densities are excessively high even for unmanaged natural stands and are ridiculously high for managed forest crops.* Tables 2 and 3 separate the information given in Table 1 into aspen and spruce components. Even when the density of each species in the mixture is reviewed, it is still excessively high. Thus the SF% and RSDIs for aspen alone (Table 2) range from 12.9 and 2971 at 20 years to 25.7 and 944 at 100 years. Although the SF% and RSDI values enter the acceptable range after 70 years, this is only because of aspen mortality and dominance by the white spruce. The SF% and RSDIs for white spruce alone (Table 3) range from 33.0 and 714 at 20 years to 13.8 and 2481 at 100 years. Although the SF% and RSDI values indicate very low densities up to 30 years, the density of white spruce is excessive between 30 and 100 years.

In order to grow spruces and intolerant hardwoods as optimally managed crops (Day 1985), they should be either naturally regenerated and spaced (noncommercially thinned at an early age) or planted at densities that allow the crop to grow actively to the minimum commercial diameter at breast height (dbh), or either harvested when they reach the minimum SF% or maximum RSDI selected for the species or thinned at this point and grown to larger dbh.

The optimum SF% and RSDI ranges for spruce and intolerant hardwoods, based on managed crop data from the U.K. (Hamilton and Christie 1971; Edwards and Christie 1981) are as follows:

	SF%	RSDI
Spruce	16.0–19.0	3700–2800
Intolerant hardwoods	21.0–25.0	2000–1500

Table 4 presents a hypothetical crop plan written directly from the United Kingdom's *Forest Management Tables (Metric)* for Site Index 23.2 Norway spruce. In spite of the custom of planting at overly tight spacing (5 × 5 ft.) in 1901, corrective noncommercial thinning in 1921 reduced the density of this stand to an SF% of 19.4 and an RSDI of 2853. The stand was then maintained at an optimum SF% and RSDI range to maturity.

Table 5 presents a hypothetical crop plan for Site Index 22.5 white spruce. To overcome the need for expensive noncommercial thinning, the stand is either planted at 2.5 × 2.5 *m* (1975 stems/ha) for pulp production or at 2.04 × 3.06 m (1975 stems/ha) for pulp (thinnings) and sawlog production (rectangular spacing allows machinery access for thinning). The stand is then either grown for 30 years and harvested for pulp with an average diameter of 15 cm or thinned successively after 30 years for sawlog production. Ideally the stand should be kept in an SF% range of 16.0 to 19.0.

Table 6 presents a hypothetical crop plan for Site Index 22.5 aspen. After logging, the stand is treated and allowed to resucker. As soon as the suckers reach 3–4 m in height, they are spaced to 2.75 × 2.75 m (1322 stems/ha) for pulp production or to 2.25 × 3.37 m (1322 stems/ha) for pulp (thinnings) and sawlog or veneer production (rectangular spacing allows machinery access for thinning). The stand is then either grown for 20 years and harvested for pulp with an average diameter of 26 cm or thinned successively after 20 years for sawlog or veneer production. Ideally the stand should be kept in an SF% range of 21–25. The prescriptions for both white spruce and aspen are based on managing each species in an optimal density range using functions of the 3/2 Rule. For simplicity, stand density is determined by selecting a desirable range of SF% and spacing each stand wide enough initially to avoid noncommercial thinning. The SF% range selected for midtolerant white spruce is from a minimum of 16 to a maximum of 19. The SF% range selected for intolerant aspen is from 21 to 25.

Although both prescriptions were developed for white spruce–aspen that was Site Index 22.5 (Johnstone 1977), they could probably be effectively implemented after harvesting on any of the better trembling aspen–spruce sites in the B.18a Mixedwood Section.

SILVICULTURAL PRESCRIPTIONS

Constraints

There are no constraints—these are good hardwood or conifer sites. They can be clear-cut and subjected to

Table 1. Hypothetical characteristics of Site Index 22.5 trembling aspen–white spruce stands in the B.18a Mixedwood Section (after Johnstone (1977)

Age	Top height (m) Trembling aspen	Top height (m) White spruce	Stems/ ha	Spacing interval[a] (m)	Spacing Factor (%)	RSDI[b]	Dbh[c] (cm)	Basal area) (m²/ha)
20	12.9	5.4	6669	1.22	9.4	3847	7.0	25.9
30	17.9	8.9	5985	1.29	7.2	4241	8.0	30.2
40	22.1	12.7	4270	1.53	6.9	4243	10.0	33.3
50	24.5	16.4	2943	1.84	7.2	4102	12.4	35.4
60	27.8	19.7	2077	2.19	7.8	3803	15.1	37.0
70	29.6	22.5	1542	2.54	8.6	3786	17.8	38.3
80	30.8	24.7	1195	2.89	9.8	3656	20.5	39.3
90	31.4	26.5	974	3.20	10.2	3562	23.0	40.3
100	31.8	27.4	817	3.50	11.0	3484	25.3	41.1

[a] Mean distance between living trees.
[b] Reineke's Stand Density Index.
[c] Diameter at breast height.

Table 2. Hypothetical characteristics of the trembling aspen component of Site Index 22.5 stands in the B.18a Mixedwood Section (after Johnstone (1977)

Age	Top height (m)	Stems/ ha	Spacing interval[a] (m)	Spacing Factor (%)	RSDI[b]	Dbh[c] (cm)	Basal area) (m²/ha)
20	12.9	3564	1.68	12.9	2971	8.9	22.17
30	17.9	1508	2.58	14.3	2190	12.7	19.10
40	22.1	802	3.53	15.9	1752	16.5	17.15
50	25.4	500	4.47	17.6	1486	20.1	15.87
60	27.8	341	5.41	18.7	1303	23.6	14.92
70	29.6	254	6.27	21.2	1177	26.7	14.32
80	30.8	202	7.04	22.8	1076	29.2	13.53
90	31.4	170	7.66	24.4	1004	32.1	13.00
100	31.8	150	8.16	25.7	944	32.5	12.44

[a] Mean distance between living trees.
[b] Reineke's Stand Density Index.
[c] Diameter at breast height.

Table 3. Hypothetical characteristics of the white spruce component of Site Index 22.5 stands in the B.18a Mixedwood Section (after Johnstone 1977)

Age	Top height (m)	Stems/ ha	Spacing interval[a] (m)	Spacing Factor (%)	RSDI[b]	Dbh[c] (cm)	Basal area) (m^2/ha)
20	5.4	3105	1.79	33.0	714	3.9	3.7
30	8.9	4477	1.49	16.7	1810	5.6	11.1
40	12.7	3468	1.69	13.4	2318	7.7	16.1
50	16.4	2443	2.02	12.3	2481	10.1	19.5
60	19.7	1736	2.40	12.2	2521	12.7	22.1
70	22.5	1283	2.79	12.4	2543	15.5	24.1
80	24.7	993	3.17	12.8	2528	18.2	25.8
90	26.5	804	3.52	13.3	2522	20.8	27.3
100	27.9	667	3.87	13.8	2481	23.2	28.7

[a] Mean distance between living trees.
[b] Reineke's Stand Density Index.
[c] Diameter at breast height.

Table 4. Crop plan for a Norway spruce plantation in the United Kingdom; Yield Class 16, Site Index 23.2 (Hamilton and Christie 1971)[a]

Date	Age	Silvicultural operation	Top height (m)	Stems/ha	Spacing interval[b] (m)	Spacing Factor (%)	RSDI[c]	Dbh[d] (cm)	Basal area (m^2/ha)	Rings/ cm	Min. ring width (mm)
1900	−1	Prepare site with Parkinson Iron Works plow									
1901	0	Plant 2+2 Norway spruce at 5 × 5 ft. (1.68 × 1.68 m), 4305 stems/ha									
1903	2	Weed the crop with old-age pensioners swinging billhooks									
1916	15	Measure stand	6.7	3778	1.63	24.3	2262	7.2	15.5	4.17	2.40
1921	20	Thin - Before	9.4	3778	1.63	15.3	3766	9.9	29.6		
		- After		2992	1.83	19.4	2853	9.7	22.1	4.12	2.43
1926	25	Thin - Before	12.2	2992	1.83	15.0	4133	12.3	35.5		
		- After		1902	2.29	18.7	2694	12.5	23.4	4.00	2.50
1931	30	Thin - Before	14.9	1902	2.29	15.4	3731	15.4	35.2		
		- After		1318	2.75	18.5	2745	16.0	26.5	3.75	2.67
1941	40	Thin - Before	19.5	1318	2.75	14.1	4227	21.1	46.2		
		- After		758	3.63	18.6	2858	23.4	32.5	3.42	2.93
1951	50	Thin - Before	23.2	758	3.63	15.6	3887	28.5	48.3		
		- After		518	4.39	18.9	2893	30.1	36.9	3.32	3.01
1961	60	Thin - Before	26.3	518	4.39	16.7	3678	35.1	50.1		
		- After		388	5.08	19.3	2891	36.2	40.0	3.31	3.02
1971	70	Harvest crop	28.7	388	5.08	17.6	3497	40.9	50.9	3.42	2.92

[a] Mean Spacing Factor percentage minimum = 16.0, maximum = 19.0; optimum rotation is 66 years (line between 60 and 70 years); 50.9 m^2/ha of basal area are produced in the main stand; 63.5 m^2/ha of basal area are produced as thinnings = 55.5% of the total.

[b] Mean distance between living trees.

[c] Reineke's Stand Density Index.

[d] Diameter at breast height.

Table 5. A hypothetical crop plan for a Site Index 22.5 white spruce plantation in the B.18a Mixedwood Section (after Johnstone 1977)[a]

Date	Age	Silvicultural operation	Top height (m)	Stems/ha	Spacing interval[b] (m)	Spacing Factor (%)	RSDI[c]	Dbh[d] (cm)	Basal area (m^2/ha)	Rings/ cm	Min. ring width (mm)
1900	−1	Prepare site with a powered disk trencher with disks set at a width of 2.5 m									
1989	0	Plant 2+2 white spruce at 2.25 × 2.25 m (1975 stems/ha) for pulp and at 2.04 × 3.06 m (1975 stems/ha) for pulpwood and sawlogs to provide access									
1992	3	Spray release with 0.75 kg/ha active ingredient of glyphosate (Vision) to set back the aspen suckering									
1999	10	Weed and space	3.0	1800	2.36	Use motorized saws					
2009	20	Measure stand	9.4	1759	2.38	25.3	2875	13.7	25.9	2.92	3.42
2019	30	Thin – Before	14.9	1759	2.38	16.0	3209	14.7	30.2		
		– After		1247	2.83	19.0	2275	14.7	21.4	4.08	2.45
2029	40	Thin – Before	19.5	1247	2.83	14.5	3230	18.4	33.3		
		– After		728	3.71	19.0	1886	18.4	19.4	4.35	2.30
2039	50	Thin – Before	23.2	728	3.71	16.0	3005	24.8	35.4		
		– After		514	4.41	19.0	2122	24.8	25.0	4.03	2.48
2049	60	Thin – Before	26.3	514	4.41	16.8	2901	30.3	37.0		
		– After		400	5.00	19.0	2257	30.3	28.8	3.96	2.52
2059	70	Harvest Crop	28.7	400	5.00	17.4	2814	34.9	38.3		

[a] Mean Spacing Factor percentage minimum = 16.0, maximum = 19.0; optimum rotation is estimated to be 65 years (line between 60 and 70 years); it should be possible toclear-cut the stand for pulpwood at 40 years; 38.3 m^2/ha of basal area are produced in the main stand; 41.3 m^2/ha of basal area are produced as thinnings = 52% of the total.
[b] Mean distance between living trees.
[c] Reineke's Stand Density Index.
[d] Diameter at breast height.

Table 6. A hypothetical crop plan for a Site Index 22.5 trembling aspen crop in the B.18a Mixedwood Section (after Johnstone 1977)[a]

Date	Age	Silvicultural operation	Top height (m)	Stems/ha	Spacing interval[b] (m)	Spacing Factor (%)	RSDI[c]	Dbh[d] (cm)	Basal area (m^2/ha)	Rings/ cm	Min. ring width (mm)
1988	−1	Prepare site by ripping, disking, or chopping to promote suckering									
1991	2	Check reproduction	5000–10000								
1994	5	Weed and space	4.0	1322	2.75	Use motorized saws					
2009	20	Thin – Before	12.9	1322	2.75	21.3	2673	15.7	25.9	2.55	3.93
		– After		961	3.23	25.0					
2019	30	Thin – Before	17.9	961	3.23	18.0	2835	20.0	30.2		
		– After		499	4.48	25.0	1472	20.0	14.1	3.00	3.33
2029	40	Thin – Before	22.1	499	4.48	20.3	2874	30.7	33.3		
		– After		327	5.53	25.0	1884	30.7	21.8	2.60	3.83
2039	50	Thin – Before	25.4	327	5.53	21.8	2531	37.1	35.4		
		– After		248	6.23	25.0	1919	37.1	28.6	2.69	3.71
2049	60	Harvest crop	27.8	248	6.23	22.4	2461	43.5	37.0	2.75	3.71

[a] Spacing Factor perentage minimum = 21.0, rising to 24.0; mean Spacing Factor percentage maximum = 25.0; optimum rotation is estimated to be 55 years (line between 50 and 60 years); it should be possible to clear-cut the stand for pulpwood at 30 years; 37.0 m^2/ha of basal area are produced in the main stand; 34.4 m^2/ha of basal area are produced as thinnings = 48% of the total.

[b] Mean distance between living trees.

[c] Reineke's Stand Density Index.

[d] Diameter at breast height.

weed control measures before and after harvesting and to site preparation measures without fear of soil erosion or deterioration. The effect of harvesting on nutrient recycling should be monitored, especially as full tree harvesting is recommended.

Prescriptions

1) Harvesting method: Harvest in large clear-cut blocks (greater than 50 ha in area).

2)a. Regeneration method for white spruce crops: Weed tree poisoning before clear-cutting, clear-cutting, heavy site preparation, planting large transplant white spruce stock, and at least two weedings with herbicide are recommended.

2)b. Regeneration method for aspen crops: Clear-cutting and heavy site preparation or rapid prescribed burning to promote healthy root suckering are recommended.

3)a. Site preparation methods for white spruce crops: Before clear-cutting, poison the aspen component of the stand by making spot applications of Velpar-L (hexazinone) to the soil at the base of all residual aspen trees at least 1 year in advance of cutting to eliminate or reduce resprouting. After clear-cutting it may be necessary to control competition by aerial spraying glyphosate (Vision) at 2.0 kg/ha active ingredient, applying hexazinone (Velpar-L) at 2.5 kg/ha active ingredient in spots to the soil in a grid pattern, or applying Esteron-6E (2,4-D) in fuel oil to the cut surfaces of resprouting stumps of aspen and other hardwoods. Unless the resuckering and resprouting hardwoods have been effectively controlled, site preparation with powered disk trenchers, heavy disks, rollers or crushers, or heavy drags is essential for plantation establishment.

3)b. Site preparation methods for aspen crops: Ripping, disking, chopping or crushing, or rapid prescribed burning are recommmended to promote healthy resuckering.

4) Planting methods for white spruce crops: Plant fresh or overwinter-stored and conditioned 2+2 white spruce transplants as soon as the field soil warms to 5°C or higher in the spring. If planting fails, replant or refill the year after planting, as required.

5)a. Initial spacing of white spruce crops: Pulpwood crops of white spruce should be planted in square spacing at 2.5 × 2.5 m (1975 stems/ha). Pulpwood and sawlog crops should be planted in rectangular spacing at 2.04 × 3.06 m (1975 stems/ha) to allow 3 m between rows for harvesting the first thinnings. Rectangular spacing with a between-row spacing of 1.0:1.5 will not cause difficulties with tree form, provided that the stand is thinned on schedule.

5)b. Initial spacing of aspen crops: Space aspen suckers when they are approximately 5 years old or reach 4 m in height (whichever comes first). For pulpwood crops, space the saplings to 2.75 × 2.75 m (1322 stems/ha). Aspen crops spaced in this manner will produce merchantable pulpwood much sooner than those at high natural densities. For sawlog or veneer crops, space the saplings to 2.25 × 3.37 m (1322 stems/ha) to allow 3 m or more between the trees for harvesting first thinnings.

6)a. Weeding and cleaning white spruce crops: As both woody competition and grass will be severe, it will be necessary to weed conifer crops two or more times to ensure that the planted reproduction grows out of the grass and overtops the brush on this site. Weeding may be carried out by mechanical methods, but it is better to use herbicides. Glyphosate (Vision) may be applied at from 7.5 to 1.0 kg/ha active ingredient from mid- to late August. Glyphosate is recommended because it controls both grass and brush species, particularly aspen. Esterone 6E (2,4-D) may be applied after mid-June to control brush overtopping the spruces. It may be applied in mid-June over white spruce crops. Because grass and raspberry are not controlled by 2,4-D, successful brush control is often accompanied by a great increase in these. White spruce plantations on frost-prone sites should be allowed to reach 2.5–3.0 m in height before they are released by aerial spraying, or else damage from late spring frost may be severe.

6)b. Weeding and cleaning aspen crops: This will not be required.

7)a. Tending white spruce crops: Pulpwood crops of white spruce will probably reach 15 cm dbh at 30 years and can be harvested then if desired. Pulpwood and sawlog crops should be thinned at age 30 to an SF% of 19 and then successively thinned so that the crop remains in the 16–19 SF% range until it reaches the required diameter for the product.

7)b. Tending aspen crops: Pulpwood crops of aspen will probably reach 15 cm dbh at age 20 and can be harvested then if desired. Pulpwood and sawlog crops should be thinned at age 20 to an SF% of 25 and then successively thinned so that the crop remains in the 21–25 SF% range until it reaches the required diameter for the product.

CONCLUSION

It is my sincere hope that the information presented in this paper will spur foresters working for industry and government in the B.18a Mixedwood Section to think more carefully about the crop species they select and the silvicultural work they must undertake to grow the first managed crops in this productive and important part of Canada.

Although the crop plans I have presented are probably not sufficiently well developed for direct application, they point toward the silvicultural methods that must be used in the future. These methods include steps:

1) Prepare site and regenerate to produce vigorous reproduction.

2) Eliminate or reduce competition from unwanted species.

3) Space the trees wide enough to avoid uneconomic, noncommercial thinning. Space square for pulpwood but rectangular (1.0:1.5 ratio) to permit easier access for thinning when sawtimber or veneer is to be produced.

4) Keep the crop in a desirable SF% or RSDI range to prevent growth check from severe competition. When producing pulpwood, harvest the crop before the density becomes too high (soon after the SF% minimum or RSDI maximum is reached). When producing sawtimber or veneer, thin the crop when the minimum SF% or maximum RSDI is reached.

5) Write your own crop plan based on your own objectives. If you copy our crop plans, do not blame us if everything does not work out. Good luck!

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INSECTS AND DISEASES OF THE MIXEDWOOD FOREST: PROBLEMS OR OPPORTUNITIES?

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Insects and diseases can have a significant effect on forest stand productivity. Although sound estimates of annual volume losses from the combined effects of insects and diseases are difficult to make, there is a perception that for Canada these losses may equal, on average, the annual losses attributed to forest fires. Except for a few instances, insects and diseases have been traditionally ignored in the plans prepared to manage stands in the northern mixedwood forest. In these plans, therefore, the amount of timber required to supply the wood-using industry is obtained by expanding the area from which wood is harvested to offset the losses caused by insects and diseases. As long as the forest resource is not fully allocated to wood-using concerns, and presuming that unlimited opportunities to expand forestry operations exist, the major effects of insect and disease losses are the increased transportation and harvesting costs incurred by operating in an area larger than required had the insect and disease losses not been anticipated.

Naturally, the forest resource is finite, and in some regions of the northern mixedwood forest, most of the resource will soon be allocated to different forestry concerns. The impact of forest insect and disease losses in these forests will depend to a great extent on the objectives of the forest manager. These effects will represent both problems and opportunities for managers and argue strongly for the development of pest management systems for inclusion in future resource management plans. Before pest management systems can be developed, however, some understanding of the manner in which insects and diseases affect forest stand development is necessary.

Recent publications on pollution damage to forest vegetation (Malhotra and Blauel 1980), forest tree diseases (Hiratsuka 1987), and tree and shrub insects (Ives and Wong 1988), coupled with exhaustive reviews by Davidson and Prentice (1967), Hinds (1985), and Jones et al. (1985), obviate the need to review all the biotic and abiotic agents that damage trees in the northern mixedwood forest. Further, the problem of aspen decay was the subject of several papers presented at a recent workshop (Northern Forestry Centre 1987) and a review by Hiratsuka and Loman (1984). My objective in this paper is to forego the traditional recitation of pest species lists and descriptions of life cycles and to concentrate on describing the effects of selected insects and diseases on the development of mixedwood stands.

Graham et al. (1963) described the autecology of aspen (*Populus tremuloides* Michx.) in Michigan and commented on the natural regeneration of pure aspen stands following fire. They also described the succession of species in these stands that produce mixedwood stands. Of particular interest to foresters of the northern mixedwood forest is the invasion, establishment, and growth of white spruce (*Picea glauca* (Moench) Voss) as an understory tree. Because of the importance of spruce, and the increasing importance of aspen to the wood-using industry in this region, it is instructive to understand the agents that influence the development of mixedwood stands so common in western Canada and Alaska.

The forest tent caterpillar (*Malacosoma disstria* Hbn.) may regulate the productivity of aspen stands, according to Mattson and Addy (1975). Although their conclusions were based on simulations of aspen stands, the simulacra they presented on stand productivity with and without defoliation provide us with an opportunity to discuss the significance of forest tent caterpillar defoliation on stand development. They modeled the annual production of stem wood, foliage production, and tent caterpillar biomass production in stands initially 26 years old to age 40. They provided data for a stand that was completely defoliated for 3 consecutive years in one forest tent caterpillar outbreak and contrasted them with data from an unaffected stand.

Mattson and Addy's (1975) simulation suggests that annual stem wood biomass production and foliage production are increasing functions of stand age over the period modeled (Fig. 1). In contrast, when the trees are defoliated by the tent caterpillar the stem wood and foliage production functions are drastically altered (Fig. 2). Stem wood production decreases from its normal value shortly after the onset of the outbreak and shows some degree of recovery in the latter half of the period modeled. At the same time foliage production is initially depressed in response to light feeding, but then climbs to abnormally high values before returning to a normal

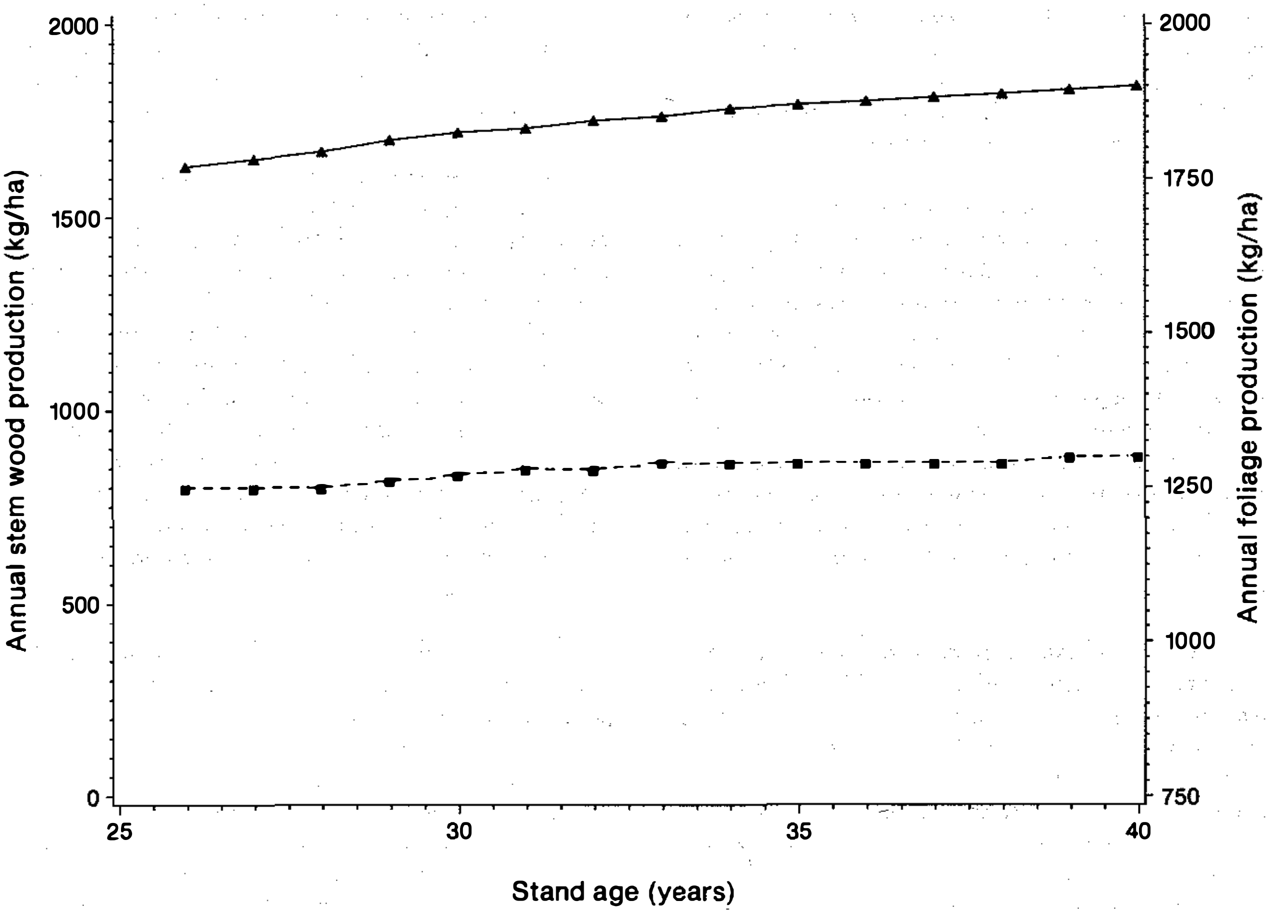

Figure 1. Annual stem wood (solid line) and foliage production (broken line) in a simulated aspen stand without forest tent caterpillar defoliation. (Source: Mattson and Addy 1975.)

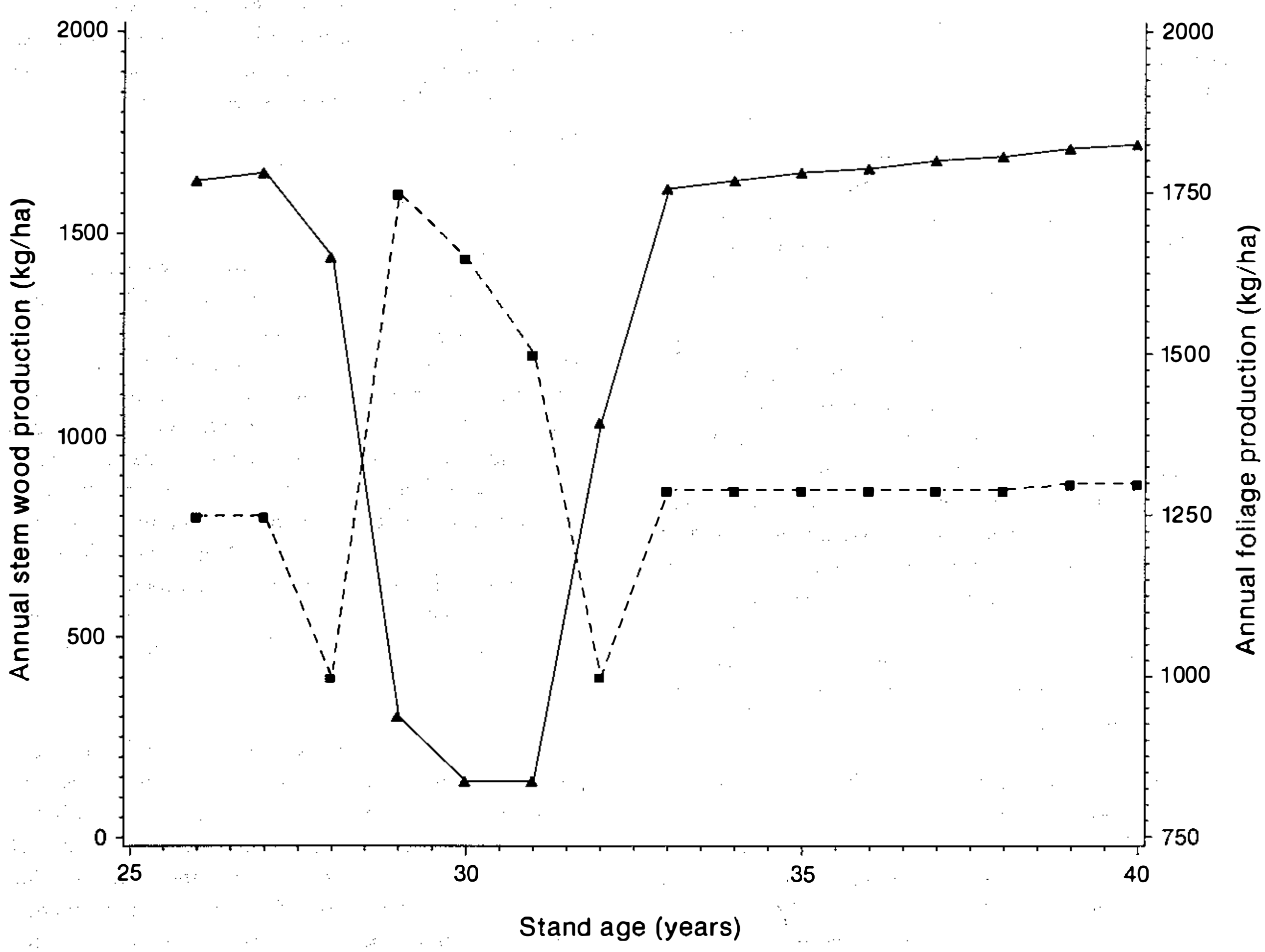

Figure 2. Annual stem wood (solid line) and foliage production (broken line) in a simulated aspen stand defoliated by the forest tent caterpillar. (Source: Mattson and Addy 1975.)

sequence of values. The counter-intuitive behavior of the foliage production function is real and reflects the response of the trees when tent caterpillar population densities are extreme (Fig. 3). The years in which caterpillars completely defoliate aspen stands are the ones in which the trees produce a second crop of foliage, accounting for the extreme foliage production values (Fig. 4). The simulations also suggest that even with light defoliation in response to low populations at the beginning of the outbreak, there is some depression in stem wood production and the recovery to post-outbreak levels of production is not complete for 2 years following the population crash (Fig. 5). More serious, perhaps, is the suggestion that stem wood production never fully recovers when compared to the stand in which no defoliation occurred (Fig. 6). The cumulative effect of the years of lost stem wood productivity in the defoliated stand is an ever-widening gap between the damaged and undamaged stand (Fig. 7). This widening gap is the result of the failure of the post-outbreak stand to recover to stem wood production levels achieved by the undamaged stand.

Mattson and Addy (1975) did not specify the causes of the loss of stem wood production; however, Churchill et al. (1964), in a study of several aspen stands 6 years following defoliation by tent caterpillars in Minnesota, found a general trend toward increasing total stem mortality with increasing severity and duration of the outbreak (Fig. 8A). Only a small portion of the total mortality could be accounted for by other insects (Fig. 8B), but this proportion seemed to become significant only in the most severely defoliated stands. A more significant source of mortality was due to *Hypoxylon* spp. infections. The proportion of trees affected by this disease shows an almost steady increase with increasing outbreak severity (Fig. 8C). Mechanical damage and other biotic and abiotic agents that could be identified showed no relationship between the mortality due to these causes and increasing severity of the outbreak. By far the largest source of mortality was that due to unknown causes. Again, only in the stands most severely defoliated was there an increased level of mortality (Fig. 8D). Churchill et al. (1964) speculated that this mortality might be a direct effect of repeated defoliation by the forest tent caterpillar.

The net result of defoliation by the forest tent caterpillar outbreaks seem to be considerable stem wood volume reduction (as much as 25% by Mattson and Addy's (1975) simulations) largely, it would appear, because of stem mortality from a variety of causes (Churchill et al. 1964). One can only speculate about the effects of these outbreaks in the northern mixedwood forest. Conditions in the northern mixedwood forest are different and the effects on the trees of the understory have not been investigated. Outbreaks of the tent caterpillar seem to be more frequent in this region and occur over larger areas (see annual forest insect and disease reports published by the Canadian Forestry Service). Whether this results in an accelerated decline of the aspen component of stands in the prairie provinces, or the tent caterpillar interacts with aspen differently, is not certain. It would appear, however, that repeated defoliation of aspen would be reflected in compensatory growth in the understory stand.

Graham et al. (1963) mentioned the value of the aspen overstory in protecting developing understory white spruce from attack by what is now regarded as the white pine weevil (*Pissodes strobi* Peck). If the aspen overstory is removed prematurely, then the risk of white pine weevil attack on white spruce terminal shoots increases dramatically. It appears that the spruce understory becomes less susceptible to this attack at about the stage in stand development when the spruce starts to form part of the upper canopy and the aspen component in the stand starts to decline. The stage at which stand productivity can be maximized by harvesting the aspen overstory should be determined for mixedwood stands of this region. The harvesting schedule proposed by Lorne Brace and Imre Bella at this symposium has merit in that the coniferous understory is left to develop largely free from risk of weevil attack.

If aspen production is not the prime objective of stand management, then forest tent caterpillars present an opportunity to thin stands at a rate that might minimize the risk of weevil attack while maximizing yields from the coniferous understory. This assumes that we are able to regulate forest tent caterpillar populations to this end. The use of tent caterpillars in this fashion has the appeal of being species-specific, environmentally safe, and probably fairly inexpensive to manipulate over the vast areas to be managed. Conversely, if aspen production is the prime objective of management, then the tent caterpillar represents a problem for the manager of mixedwood forests who makes plans that ignore this organism.

In conclusion, insects and diseases in the northern mixedwood forest may represent both problems and opportunities. Whether a specific organism is regarded as beneficial or a pest depends on the specific objective of the land manager. In any event, understanding the interaction of the tent caterpillar with aspen stands and secondary organisms, and the interaction among aspen defoliation, white spruce growth, and the risk of attack by the white pine weevil, is required to manage future stands of the mixedwood forest.

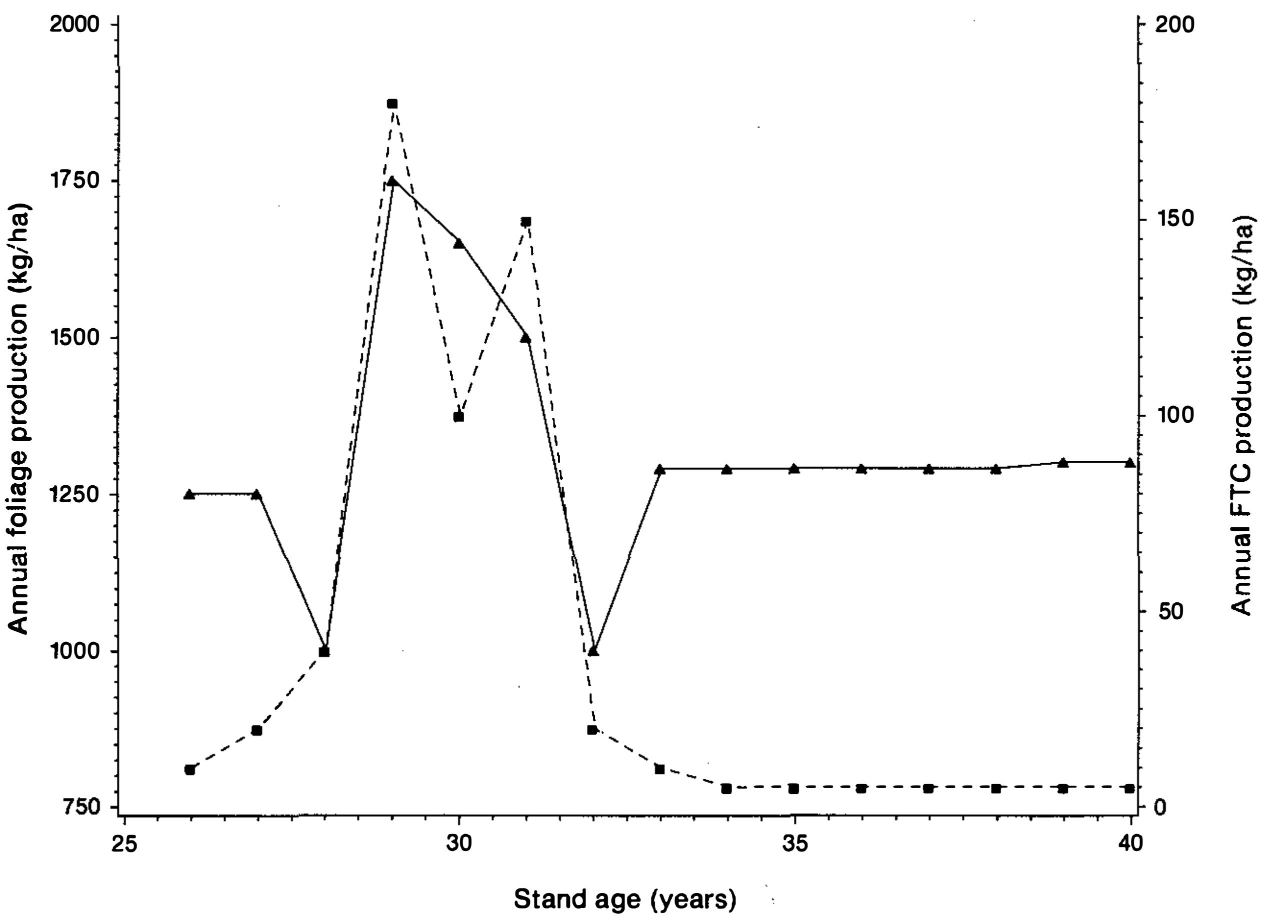

Figure 3. Annual foliage production (solid line) and forest tent caterpillar biomass production (broken line) in simulated stands with forest tent caterpillar damage. (Source: Mattson and Addy 1975.)

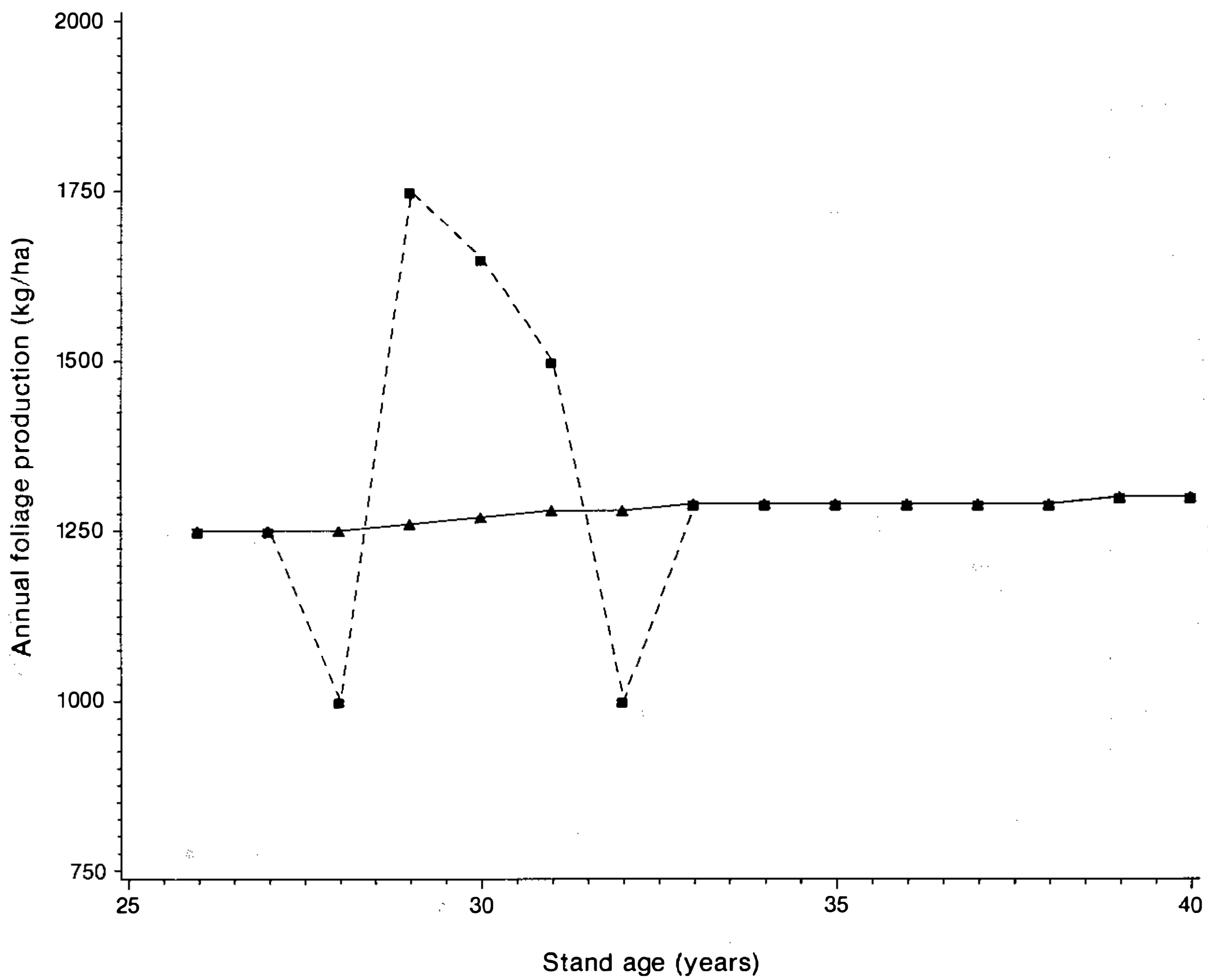

Figure 4. **Simulated foliage production in stands with (solid line) and without (broken line) forest tent caterpillar.** (Source: Mattson and Addy 1975.)

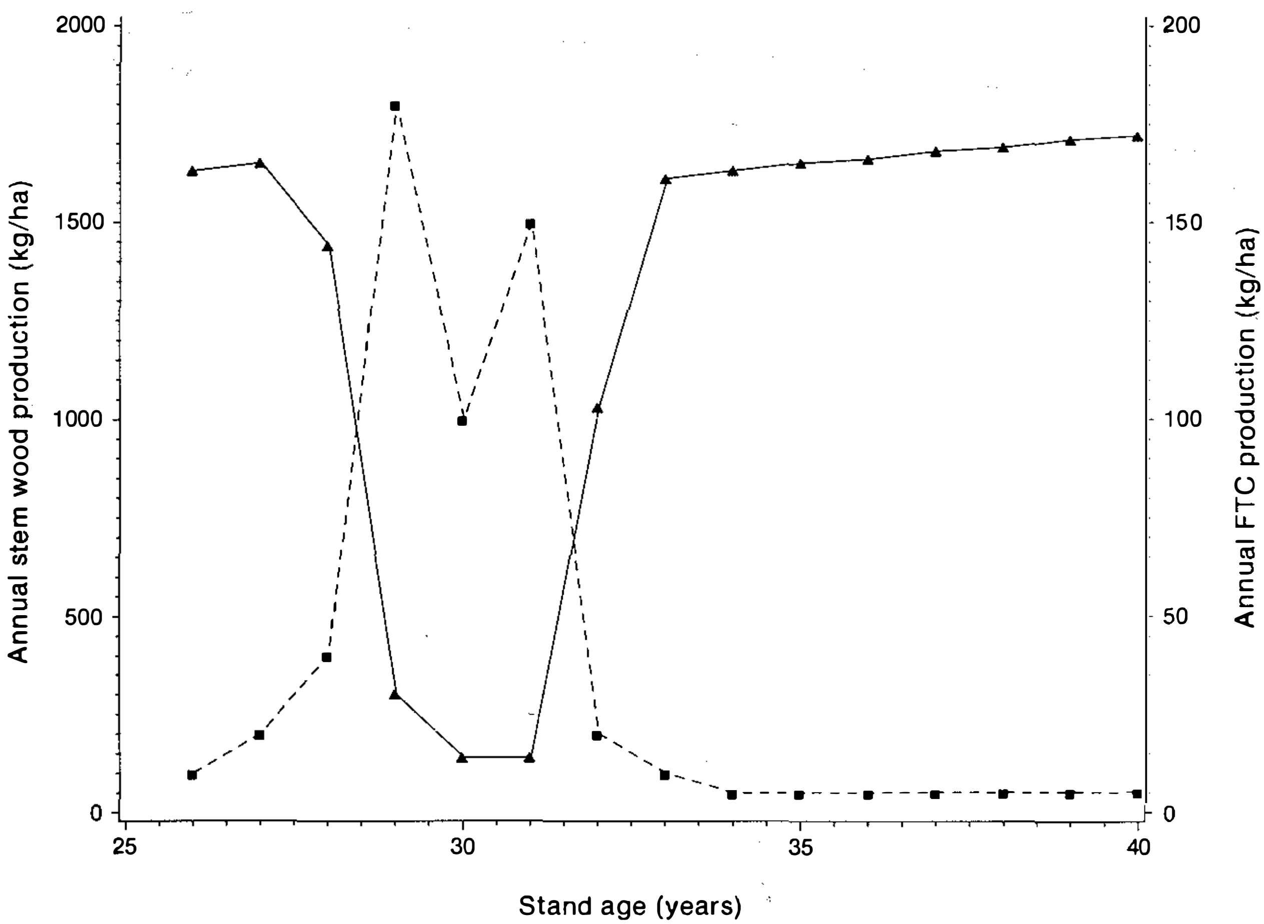

Figure 5. Simulated stem wood (solid line) and forest tent caterpillar biomass production (broken line) in the damaged stand. (Source: Mattson and Addy 1975.)

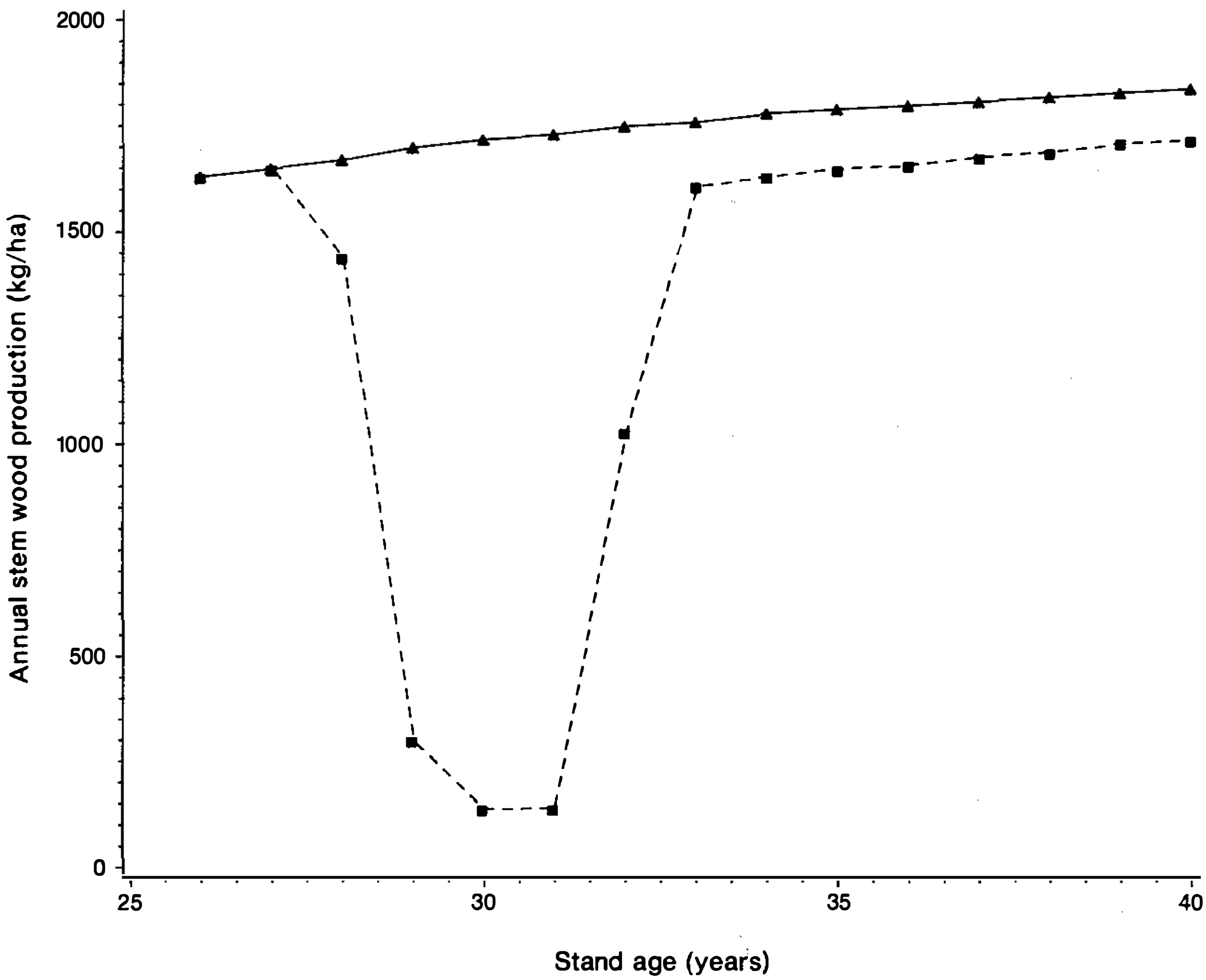

Figure 6. Simulated annual stem wood production in an undamaged (solid line) and damaged (broken line) stands. (Source: Mattson and Addy 1975).

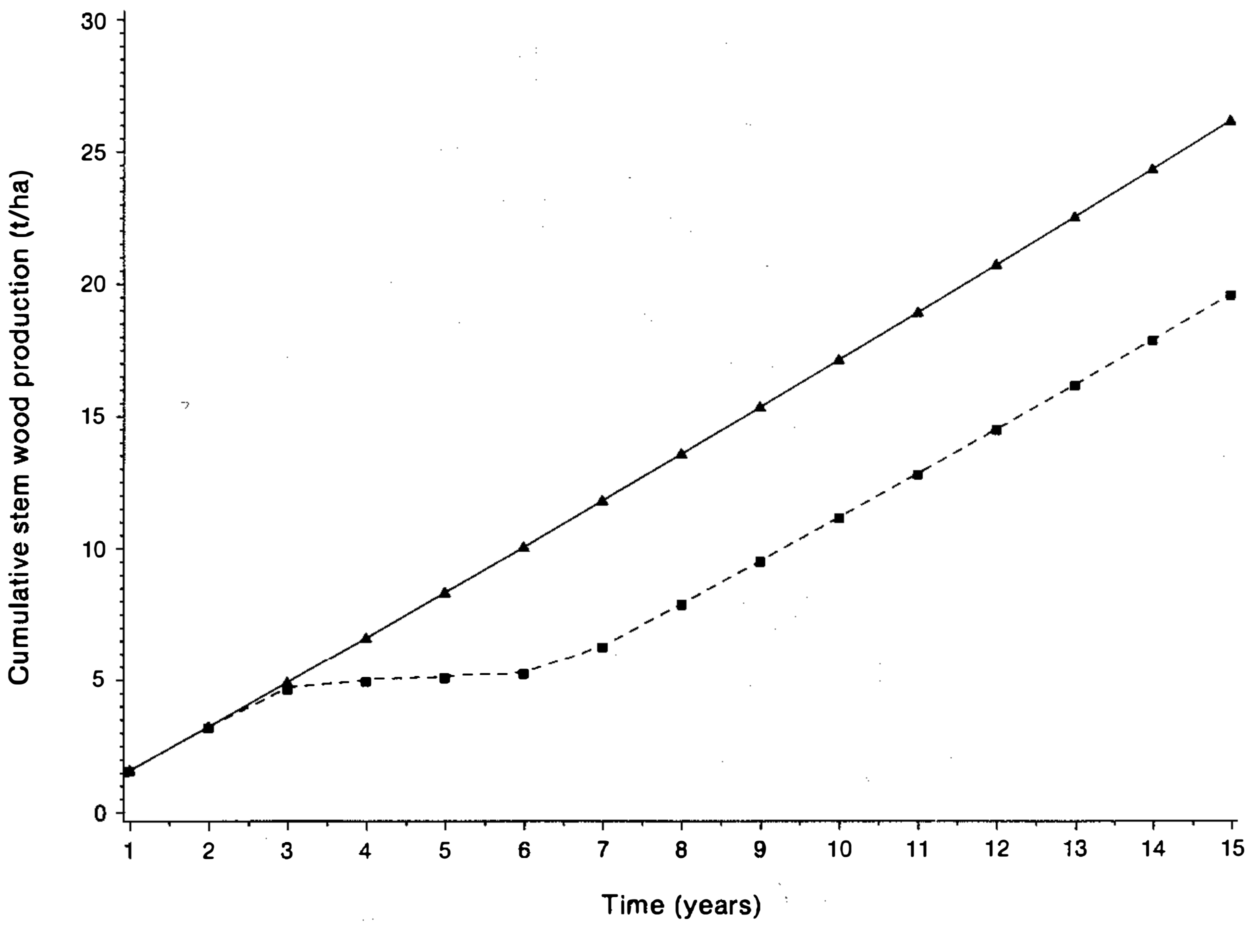

Figure 7. Cumulative stem wood production in simulated aspen stands that are undamaged (solid line) or defoliated (broken line) by forest tent caterpillar. (Source: Mattson and Addy 1975.)

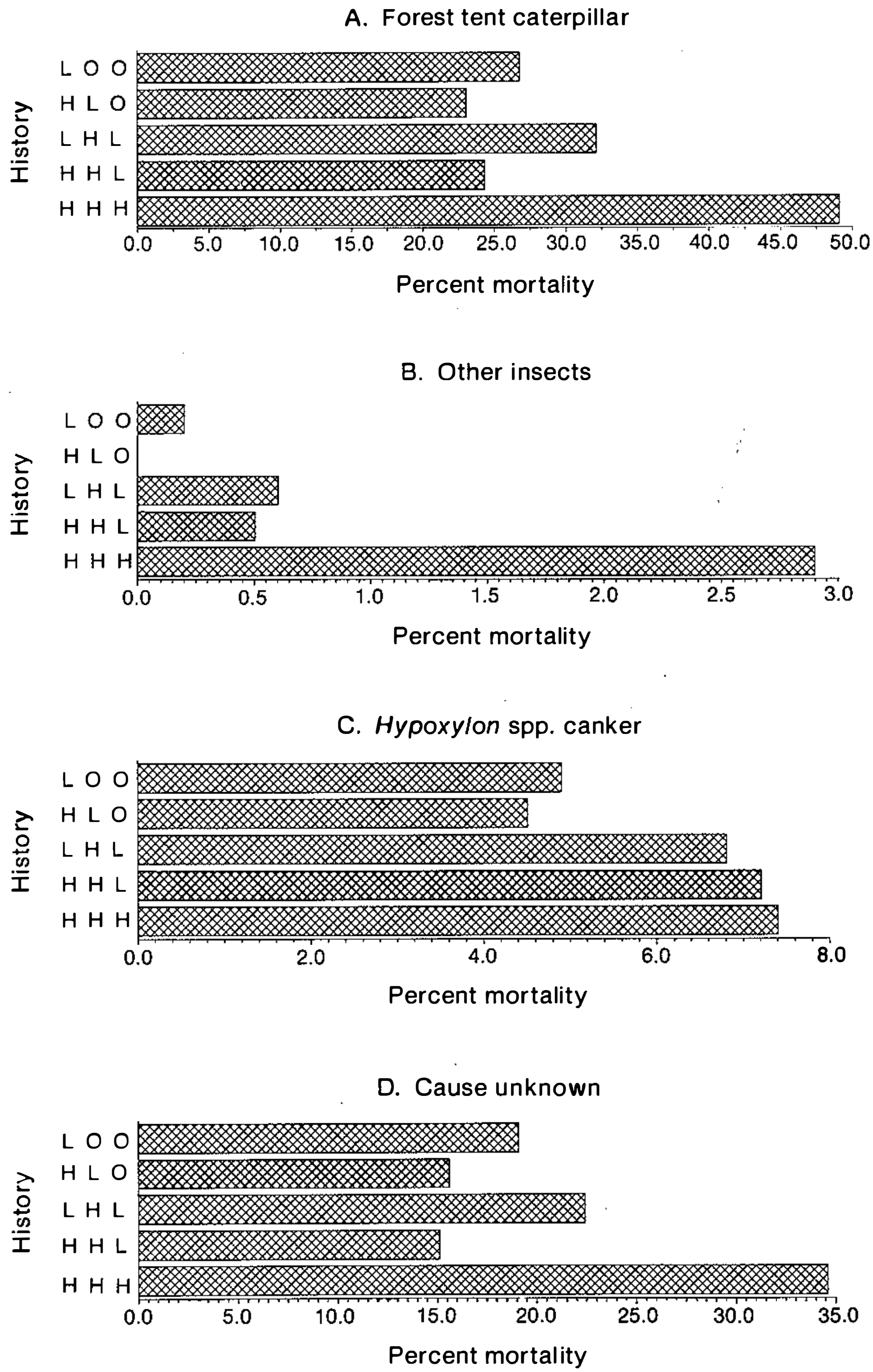

Figure 8. Tree mortality attributed to attack by various damaging agents over a 3-year period: A) forest tent caterpillar; B) insects other than forest tent caterpillar; C) *Hypoxylon* spp. canker; and D) no known cause (H = high, L = low, and O = no defoliation. (Source: Churchill et al. 1984.)

ACKNOWLEDGMENTS

I thank my colleagues H. Cerezke, Y. Hiratsuka, and K. Mallett of the Northern Forestry Centre for discussions that contributed to the genesis of this paper.

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HARVESTING NORTHERN MIXEDWOOD FORESTS IN ALBERTA

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INTRODUCTION

This paper is a very general summary of some of the concerns and issues related to mixedwood harvesting as viewed by those directly involved in logging operations.

It would be inappropriate to apply a single harvest system suitable for all sites, economic conditions, and plant manufacturing requirements. Many of the situations referred to in this paper are relevant only to the logging activities occurring on the Procter and Gamble Cellulose Ltd. forest management agreement areas near Grande Prairie, Alberta. This operation supplies softwood and aspen logs to a bleached kraft pulp mill as well as softwood logs to a dimension sawmill.

Roundwood harvesting is the starting point in the physical process of manufacturing forest products and in most cases is the single most costly element in that process. Harvesting in mixedwood stands presents some further difficulties that can add to the total manufacturing cost. It is very encouraging to see opportunities develop for utilizing softwoods and hardwoods together. The rate of this utilization will be primarily determined by the international economy. As a result, a very close relationship between commercial interests and government agencies will be required in order to develop a competitive strategy that will have long-term success in the international economy.

This review of the current and possible future harvesting systems in mixedwood stands indicates the following:

1) Most decisions center on maximizing the productivity of people and capital employed in order to provide positive contributions to business results.

2) Most of the equipment and systems employed are strongly influenced by those found in use in pure stand types that are clear-cut.

3) The trend continues toward increased mechanical harvesting in order to improve productivities. Current systems employ single-function machines; however, future system productivities will be increased with the use of multifunction machines.

4) In the short term, harvest systems that include elements of selective harvest, thinning, shelterwood, or multiple pass systems will not be as productive and as such will not predominate in any particular area.

5) In most situations, the forest manager will commit himself to either softwood or hardwood reforestation techniques. The cost of this will be recognized and perhaps even returned through improved harvesting techniques.

HARVESTING CONSIDERATIONS

To date, it has been only in rare instances that a harvest of both hardwoods and softwoods occurred in mixedwood stands. Operations tended to concentrate their cuts in the more dense coniferous or hardwood areas, from which productivity targets can be attained. The use of alternate clear-cut blocks left hardwoods as residuals.

The main, obvious, and most important requirement for complete mixedwood harvesting is that the manufacturing plants desire the hardwood component and can manufacture and sell it at a reasonable margin. They will also have quality requirements for form, decay, species, timing of cut, aging in inventory, timing of delivery, butt/top size, and length per piece.

Once this direction is in place, the logging manager must deal with the many variables occurring in the mixedwood forest. Foremost among these are the following:

1) Usually sites are wet, silty clays, and as a result much of the harvest must take place in the winter.

2) The amount of decay in hardwood species can drastically affect the decision to harvest, which is often very hard to determine.

3) Advanced softwood regeneration will often pose a problem.

4) A cost-effective method of reforestation must be determined.

5) Haul distance and type of access must be economical.

6) Hardwood densities must provide enough volume and be of the right stem diameter to fit into the harvest system.

7) It will be essential to deal with other issues such as blowdown potential, silviculture access, and other users' interests.

CURRENT HARVESTING SYSTEMS

Planning

The planning phase is one of the most important steps, and it is particularly desirable that all parties in the process participate, from the manufacturing group right through to the silvicultural group.

Roads

Access to the stands can be very expensive. Summer roads and bridges are some of the more costly elements. Most operations tend to undertake logging and hauling during frozen conditions in order to keep road building and maintenance costs to a minimum; harvesting productivity is also much higher under these conditions. The ability to use seismic lines and other access roads during frozen winter conditions minimizes damage to the environment.

Conventional Harvest

In areas where the hardwoods component is predominant but there is no current commercial use, the conventional methods of hand-falling, limbing, and topping with chain saws combined with cable skidding continue to be used. In some cases, swing boom grapple skidders are used. This system involves taking the full tree to roadside, where the trees are limbed, topped, and decked. From a safety perspective, hand-falling only the coniferous trees in these stands is dangerous as they tend to hang up easily on the hardwoods or the hardwood branches may break away and become lethal projectiles.

Mechanized Harvest

In mixedwood stands where the hardwood density is not significant or where all merchantable species can be used, the trend is toward fully mechanized operations as a direct result of a desire to reduce logging costs and increase productivity. This system moves the whole tree to the roadside, with a mechanical delimber usually located at roadside. These separate, single-function machines have the advantage of flexibility and phase independence.

The first phase used in this system usually consists of tracked or wheeled feller–bunchers using shear or saw blades to cut the stem. The ability, particularly with smaller wood, to accumulate several trees in the cutting head during each complete cycle is most desirable. Momentum circular saw blades are also becoming more popular. These saw blades increase productivity and reduce butt shatter in sawlogs. In steeper terrain, several types of these machines are able to level their upper parts to better facilitate the cutting and felling processes.

This felling process leaves the trees bunched and ready to be skidded to a roadside deck with grapple skidders. Grapple skidders allow operators to remain in an enclosed cab and operate in all weather and light conditions.

Single-stem delimbing machines have improved dramatically over the past 5 years. These machines have been able to deliver top quality wood with desired productivity levels through both summer and winter seasons. In addition to limbing, they also do an excellent job of sorting wood by diameter, end use product, and species. They also have some ability to cut out defects. Some of these machines are equipped with a type of processing head that can cut wood to specified lengths.

In areas where both the coniferous and hardwood components are logged for pulpwood, a chain flail delimber works well, particularly in the winter months. With this method, however, some tolerance of varying limbing quality will be needed in the wood room in-feed process. In hardwood stands, a topping saw mounted on a wheeled carrier may also be used to top the wood when branches and forked tops are a problem.

From strictly a harvest productivity point of view, it is most effective to clear-cut mixedwood stands if the economics of hardwood utilization are favorable. If the hardwood is not utilized, however, both the conventional and mechanized methods continue to pose problems for silviculture.

The conventional hand-falling method leaves most of the hardwoods standing and can result in high falling and skidding costs. This will reduce competition somewhat but will limit the ability to use mechanical site preparation equipment. The conventional method, if planned properly, is often very successful at reducing the damage to advanced regeneration. On the other hand, the mechanized method improves falling and skidding productivities but opens the forest up to much more competition. As well, there is a cost to falling and leaving the hardwood stems if there is no commercial use for these species.

Loading, Hauling, Unloading

At this point, the wood is ready for delivery to the manufacturing site. Where volumes are large and concentrated, the loading is accomplished with wheeled or tracked hydraulic knuckle-boom loaders. In areas where the wood is less concentrated and isolated, self-loading cherry picker truck–trailer units are used. The ability to pick up one truck load improves the flexibility of the operation to work in areas of small scattered stands.

Unloading and storage strategies in the woodyard are also a critical component to the system. Most operations build an inventory over the winter, which is then depleted through usage over the summer months. Wood can be unloaded, stored, and reclaimed with conventional wheeled machines or by cranes mounted on rail tracks.

FUTURE HARVEST SYSTEMS

If more hardwood species are utilized and solutions are found to our reforestation dilemma, the next 10–15 years will see a trend toward the complete mechanization of harvest equipment used in mixedwood stands. The conventional power saw and cable skidder will be used only in areas with difficult terrain or very large tree sizes or where high densities of merchantable but unwanted hardwoods occur.

This drive toward mechanization will be a direct result of a need to achieve higher productivities per person employed, improve safety, and reduce labor and camp costs. These changes will be needed to finance the higher reforestation costs associated with mixedwood stands.

Equipment and systems must evolve and adapt to our particular conditions in terms of both the physical and economical variables that we are charged with managing. As we will continue to harvest natural stands for quite some time, it will not be appropriate to directly copy equipment systems used in plantations or systems employed in the Scandinavian countries, where the wood supply economics are quite different. It is essential when designing a mixedwood harvest system that we take what is good in these other systems and leave the rest.

Because so much more of our wood will continue to be harvested in stands of comparatively pure coniferous species, the equipment developed for this situation will likely predominate over that needed for mixedwood harvesting. As a result, equipment will need to be flexible for use in mixedwood areas.

As the industry expands and the demand for mechanized harvesting machines grows, more emphasis will be given to designing machines specifically for the forest environment rather than to adapting machines used in the construction industry. This equipment will be engineered for strength but will be smaller and weigh considerably less. Current examples of this trend are some of the Scandinavian carriers and the evolution of feller–buncher cutting heads.

Hydraulic systems continue to improve, as witnessed by the development of high-pressure, variable-flow hydraulic systems in many current models of feller–bunchers. The quality of manufacturing has also improved, with the Japanese setting high standards.

The next 10–15 years will likely see a movement toward multifunctional machines, in particular machines that combine at least two functions. Two popular combinations of functions may be falling and delimbing or falling and transporting to roadside.

For these types of machines to be developed, further improvements are needed to increase reliability, decrease capital cost, and improve stability and gradability. The ability to train and retrain skilled operators will also be important. If these goals are met, the total productivity of the system will increase, wood will be handled less, and planning will be much improved as there will be less interdependence among functions.

Recent developments in modular multipurpose vehicles are also encouraging. These machines have carriers capable of changing their two or more functions at different times and for different purposes. More standardization is needed in the manufacturing industry with regard to the components and the carriers employed.

An increased emphasis on operator training will be an important part of the change to multifunctional machines. Much of this may take place on simulators; however, future equipment will likely be designed for easier operation. Hydraulic lever controls will have infinite settings so that an operator will be able to point the control or track it on a monitor in order to move an attachment. Many of the current control functions will be combined and made automatic to optimize the timing and give the operator more time to plan the next movement. Electronic devices will be able to monitor equipment and warn if stress or mechanical failures are occurring in the system. Operator ergonomics will also play a larger part in equipment design.

Future forest operators are likely to be more of the owner operator-contractor type. There will be a trend to lengthening the current season in order to retain a skilled work force and to improve the return on capital employed. As access improves, there will be fewer camp situations. Future transportation of operating crews to the site will involve the use of helicopters.

The trend to extending the season of operation will increase environmental pressures to reduce disturbances to the terrain. Recent improvements in low-pressure tracked machines and wide-tired skidders and forwarders is encouraging in this regard.

The future will require closer partnership among the harvesters, silvicultural operators, and manufacturing customer. These groups will need to be aligned to act together in equipment and system changes. Some of these issues will revolve around which parts of the process will occur in the woods and what will be optimal at the manufacturing site. These decisions will need to be statistically based and focus on continually improving the complete process.

Technology is moving very rapidly in the manufacturing process, with improving abilities to handle the form, size, quality, and species that our forests produce.

CONCLUSION

With increasing commercial opportunities to use hardwoods from the mixedwood forests, more harvesting methods will turn toward mechanical systems. It is likely that these systems will continue to use an alternate clear-cut pattern and, as a result, reforestation costs will increase. Over time, much of the equipment will become multifunctional, providing a more productive system to help offset some of these reforestation costs.

Sorting several different products in the woods by size and species will become more commonplace. Many of the newer plants will be designed to do some of these same functions more efficiently at the manufacturing site.

FOREST PRODUCTS INITIATIVES FOR THE 1990s

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I would like to first define the area that I intend to cover. The key word in my title is "initiatives". If we consult the dictionary, we find definitions that include meanings such as first step, introductory act, energy, aggression, desire, and ability to take the lead. I would like therefore to talk about the role that technology must play if we are to direct our energy toward developing an aggressive leadership role for the solid wood products sector, which depends upon the mixedwood forest. Before embarking on my tale of future opportunity, however, perhaps I should spend a couple of minutes to tell you where I am coming from (as the younger generation would say). Despite the gracious introduction, I am well aware, after several encounters over the past 2 days, that there are a number of people who still thirst for knowledge about Forintek. In any event, for those of you who do know me, I have a need as a representative of a nonforester minority group at this meeting to stake out my territory, so to speak.

WHAT IS FORINTEK?

Forintek is Canada's wood products research institute. We are a private sector, nonprofit corporation, 9 years young and 70 years old due to the fact that we were created in 1979 by a federal government decision to privatize the two forest products research laboratories owned and operated by the Canadian Forestry Service for about 60 years previously. In addition to our operations in Ottawa and Vancouver, we have an industry liaison office in Edmonton and a small satellite research group adjacent to Laval University in Quebec City.

We are supported by a unique funding partnership and as a result are often referred to as a cooperative research institute, similar to the Forest Engineering Research Institute of Canada (FERIC) and the Pulp and Paper Research Institute of Canada (Paprican). The funding breaks down in the following way:

Federal government: 50%
Provincial governments: 25% (B.C., Alberta, Manitoba, Quebec, New Brunswick, and Nova Scotia—we are still working on Saskatchewan and Ontario)
Industry: 25%

The partnership is contingent upon the continued maintenance of at least 25% of our revenue from industry. This support comes from 145 member companies that represent approximately 70% of the national lumber manufacturing capacity and 80% of the national panel products manufacturing capacity.

Our mission is to be the leading force in the technological advancement of the Canadian wood products industry through the creation and implementation of innovative concepts, processes, products, and education programs. To explain what we mean by "leading force" and "technological advancement", a rough translation of our mission would be "technology does not count until it happens". So, having defined my territory, I would now like to tackle the subject of future initiatives.

There is a popular view that necessity is the mother of invention. At the risk of challenging conventional wisdom, I would like to suggest that the creative process is better fostered by opportunity. If you can accept that thought, then perhaps you will buy this definition: "If opportunity is the mother of invention, then profit is the father". The point I am making is that we do not conduct research for its own sake or because it is socially acceptable. The ultimate purpose of R & D is quite simply to create wealth—call it competitive advantage or profit improvement, if you like, but the objective must always be to provide our sponsors with a return on their R & D investment. Our R & D programs, therefore, are triggered by changes in the commercial environment and are designed to address industry needs, both present and future. They are opportunity-driven.

At Forintek we manage opportunities by our Research Program Committee (RPC) process, which involves close consultation with a broad spectrum of senior people from manufacturing, marketing, forestry, the supplier community, universities, the provinces, and the federal government. The RPC role is basically to provide us with advice, guidance, and feedback relevant to our project plans and their implementation.

In addition to teaching you a little more about Forintek's *modus operandi*, I would like to suggest that our RPC model is an example of Initiative Number 1, which is to know and understand customers and their needs. So, what about our customers and their needs? Our customers, of course, are the various sectors of the Canadian wood products industry, who account for approximately 45% of the world softwood demand, which suggests that as a component of Canada's largest industrial sector (accounting for one in every seven jobs) they carry a certain amount of national status.

CHANGING TIMES FOR INDUSTRY

I am sure we all bemoan the fact that gone are the good old days, when profits abounded and wood was the universal building material. Unfortunately, as we know, industry is now facing a much tougher and quite different business climate from that which it has enjoyed in the past. There are many reasons for this, but the principal ones are rather simple. We have become highly efficient processors of a changing resource serving traditional markets with commodity products. Our markets have largely been the affluent countries of the world, and population growth in these countries is low and will continue to be low. Furthermore, without change, it is doubtful that any increase in per-capita income will be spent on wood products. Unless we change, therefore, we must expect a decline in the exports of commodity products to traditional markets. The failure of wood products prices to increase in real terms over the last 10 years or so is a symptom of the situation. Another symptom is the real fact of U.S. protectionism and resultant import duties.

Analysis of this scenario causes us to realize that the problem centers around resource quality, commodity product philosophy, and traditional markets. The solution therefore must lie in better management of our existing and future resource, maintenance of our process skills, development of new product applications, development of higher-value products, and new market initiatives.

We are slowly but surely realizing that we are experiencing the dawn of a new era, an era of intense competition in which technology must be joined with marketing and productivity if we are to solve our problems. We must also realize that the global village is now a fact of life for the wood products industry and that it is our knowledge, ingenuity, and creativity, rather than our forest resource alone, that will be the mainstays of our future prosperity. Perhaps this is Initiative Number 2; if it is not, then it certainly means that we must undergo a major change in our philosophy.

In order to address specific initiatives for the management of our complex problem, we must deal with three basic issues that every sector of the wood products industry faces today: timber supply, productivity, and competition.

Timber Supply

Timber supply is the logical starting point. Industry and government today are making large investments in the forest. The benefits of these investments will be inherited by our grandchildren. It is very important for us to realize that today's forest management decisions will have a profound effect on tomorrow's products. We must maintain our reputation for quality wood products by ensuring that the appropriate characteristics are included in our forest management programs.

For example, we know that for certain species in the managed mixedwood forest there is a significant increase in the proportion of juvenile wood in the stem, which will affect processing characteristics (for example, there could be excessive warp during drying). A wise investment today will enable us to develop technology to process tomorrow's trees efficiently, as there is no doubt that they will be quite different. Forintek's goal is to create a technical bridge between the forest manager and the manufacturer by developing the appropriate wood property data that will allow us to maximize the value of the products that will be manufactured from tomorrow's resource. At the same time, there is a need to accelerate the development of technology for the efficient processing of products from the existing mixedwood resource.

Our development (with industry and government partners) of the spindleless or centerless lathe, is a classic example of our providing the plywood industry with technology that has been specifically designed for a different type of resource. This lathe accepts 7.5-in. diameter wood and produces a 2-in. diameter core, thus allowing industry to produce more veneer from current core production and to cope with its changing wood supply. This is also an example of how higher-value products can be manufactured from a lower-cost resource through the development of new technology.

With maximum utilization of the existing resource in mind, we should pay more attention to the possibility of combining or integrating new technologies in order to address some of the challenges posed by the mixedwood forest. I am referring to biotechnology and specifically the use of bioconversion for the production of fuel, food, and chemicals from the residues of other manufacturing processes. The economic feasibility of the bioconversion process as a component of an integrated manufacturing strategy warrants further investigation.

Productivity

Turning to productivity, our first initiative for this issue should be to realize that there is still a great deal of room for improvement in the efficiency of existing operations. Our experience with sawmill improvement programs has demonstrated that the application of existing technology that does not require major capital investment can result in an average 10% reduction in operating costs. To prepare for the future, however, we must accelerate the construction of more-effective technical bridges between the wood products industry and the high-technology industry. We must incorporate advanced technologies such as artificial intelligence into our planning. A major initiative must therefore be the development of a stronger association with the electronics industry to create hardware suitable for our long-term needs. We must learn to initiate communication with other industries, as opposed to our current practice of discussing our problems with only each other.

For example, we have developed a new concept for accurately sensing the moisture content of lumber and veneer. Mill trials of the sensor have so far demonstrated benefits such as a 25% reduction in kiln drying time and a 5% increase in product value due to improved grade and yield. This concept is based on infrared sensing technology originally developed for satellite scanning programs.

The human eye has a significant impact on profitability, as it is the means whereby product grade and thus product value are determined. The eye is not infallible, however, so we are evaluating machine vision technology in order to fully automate the grading process, thus increasing yield and productivity to improve profit margins.

Competition

Before defining technological initiatives necessary to address the competition issue, I would like to remind you that we have an overriding marketing challenge. The volume of wood products used in housing, our traditional market, will continue to decline at an increasing rate. Never fear, there will still be a market for our studs and sheathing panels. We will be able to supply commodity markets as long as we remain price-competitive and as long as we offer good, consistent quality. Our real concern should be the forecast that wood products will be used in different ways due to opportunities in the industrial and nonresidential markets. These markets are populated by a different kind of customer with very specific needs. They are also markets that are fiercely competitive and populated by a different kind of competitor. The trouble is that we have allowed wood to be taken for granted. We have become so used to its widespread use that we have overlooked the fact that we have created opportunities for other materials manufactured by other industries. These industries, with their engineered products and systems, are progressively invading our housing market and are also dominating the nonresidential markets.

We know that wood works, but now we must prove it in the context of new building design codes in order to counteract the efforts of competitive industries that are working very hard to deny us our share of the market. To help the industry meet the nonresidential challenge, therefore, our initiative must be to lead the development of the necessary technical data base for all wood products that will ultimately provide the design criteria needed to convince architects and designers that wood is at least as efficient and reliable as steel and concrete in any type of building. We must also accelerate the development and use of sophisticated tools that will allow marketing engineers to offer complete nonresidential construction systems that will compete effectively with nonwood systems. We need to resurrect the worship of wood as an engineering material.

To combat competition further, we must constantly fine-tune our current manufacturing technology to improve the characteristics of existing products so that they achieve maximum market penetration at the highest possible value. We must renew our product lines so that they do not become commodities. As an example, process technology that we are currently developing to improve the dimensional stability of waferboard and oriented strand board should open up expanded applications for these products, although high humidity is currently a constraint. This type of technological initiative will also help us to cope with high-value imported products such as European laminated flooring, manufactured with hardwood faces and softwood backs—a perfect example of mixedwood utilization. Do not worry; we can modify the properties of aspen to suit the end use. We can even produce high-value, engineered laminated veneer lumber from aspen by using appropriate technology to produce the necessary strength characteristics. These examples further suggest that future manufacturing strategies should address the concept of multiple product plants that maximize the mixed blessing of the mixedwood forest.

We need to remind ourselves to take full advantage of the versatility, unique strength, and aesthetic characteristics of wood as a meansof differentiating our products to gain a greater market share.

TECHNOLOGY TRANSFER

The definition of opportunistic initiatives is one thing, but their execution is quite another. So how are we going to make all this come to pass? It would almost appear that we need an initiative to address initiatives! Remember, technology does not count until it happens! I would like to assure you, however, that effective technology transfer does not just happen—it has to be managed, and managed very, very carefully.

Rule Number 1 is that technology tranfer is too important to be left to scientists. It must be part of a company's strategic plan and must be given the same amount of care and attention as the operating plan, the financial plan, and the marketing plan. Remember that the purpose of technology is to create wealth via product and market expansion and renewal.

Rule Number 2 is that technology is not transferred by the written word. It must be demonstrated with enthusiasm and patience by all concerned, as success is often the product of elegant failure. To understand the process, it is necessary to recognize that technological advancement strategies come in all shapes and sizes.

Each strategy involves different degrees of risk and return, and each requires a progressively more complex transfer mechanism. It is vital that the transfer process is identified in as much detail as possible during development of the technical plan. Once the strategy, the plan, and the transfer mechanism are defined, they form a process that when set into motion can represent the most exciting and, at the same time, the most frustrating experience for all those concerned in its operation and management.

We call this the innovation pipeline, and basically it is a model of the business that we are in. Innovation is a word we hear often these days, but it is a word often incompletely understood. To us, innovation is the creative process whereby we convert new ideas into measurable benefits. Basically, it is a three-stage process. The process stages are creation, demonstration, and commercialization. The relationship of risk and cost changes with each state. The composition and characteristics of the operating and management team also change with each stage, and technology champions become keynote players. Champions are a rare breed that also come in all shapes and sizes, from the corporate decision-maker driven by such a desire to achieve that he would rather ask for forgiveness after the fact than ask for permission before the fact, all the way to the unsung hero of the graveyard shift who simply refuses to accept the existence of Murphy's Law.

FUNDING

As a key initiative for technological advancement, innovation requires commitment from all concerned in order for us to manage the constant change in our infrastructures and in the external environments in which we must operate. Even with all the will in the world, however, we cannot build a pipeline without resources, which brings me to my final initiative—funding the innovation process for the wood products industry.

I will resist boring you with endless statistics on this subject. Suffice it to say that private forest sector R & D funding currently represents approximately 0.3% of total sales, while total government R & D expenditures amount to 0.4%, for a total of 0.7% of total industry sales. Needless to say, increases in real terms over the years have not represented a challenge. To place the Canadian figure in perspective, one should simply note that it represents approximately one-third of the Scandinavian commitment and one-half of the U.S. investment. Again, with simple comparisons in mind, if we go to the other end of the scale and look at the growth industries involved in strategic advanced technologies, such as information systems, artificial intelligence, advanced materials, and biotechnology, we find that the comparable statistic is an R & D investment of approximately 10% of sales.

So where should we be? The answer depends on what we want to be! Indexed forinflation, 0.7% of sales is probably sufficient for a commodity-based industry that does not intend to change, but it certainly is not sufficient for an industry that is clearly committed to the development of higher-value product portfolios in the context of a market-driven operating philosophy.

CONCLUSION

In closing, I would like to congratulate the sponsors of this symposium for the timeliness of the event, particularly in view of the national initiative for science and technology currently under development by the Canadian Council of Forest Ministers. I would like once again to express my appreciation for the opportunity to talk about customers and their technological needs in this business of innovation in the wood products industry. I would like to remind you of Fred McDougall's words at our opening session, when he stressed the need for more effective communication with all concerned in the management and utilization of the mixedwood forest. Before making decisions, we all talk to our customers. From now on, however, we must involve our customers'

customers in the dialogue and build the innovation pipeline all the way from the forest to the marketplace to ensure that we have all satisfied the ultimate customer—the end user.

In the global economy, success will come only to those who have made technological innovation an indispensable component of their business plan. Based on the experience of Forintek and its partners, we know that there is only one thing riskier than innovation—and that is not doing it.

HIGH-YIELD PULPS FROM CANADIAN HARDWOODS

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INTRODUCTION

Up to now, softwoods in North America have been so readily available that hardwoods, despite their widespread presence, have been largely neglected as a source of raw material for the pulp and paper industry. Table 1 provides a summary of incremental softwood and hardwood fiber supply for Canada (Woodbridge, Reed and Associates 1982). This table indicates clearly that Canada has significantly larger hardwood than softwood resources[1]. Of the total 32 million m³ of hardwood available annually, approximately 65% of this amount is poplar, with birch and maple amounting to additional amounts of 23% and 9%, respectively. Though these figures represent incremental fiber supply, they should not be construed as total available supply, because the amounts indicated certainly contain wood that is infected to a greater or lesser degree and is therefore unsuitable for any form of pulping.

The amount of essentially untapped hardwood available nonetheless is staggering. Furthermore, because the wood is distributed throughout Canada, it is perhaps not surprising that a substantial amount of research and development work has been initiated during recent years to assess the potential of hardwoods as a source of raw material for the pulp and paper industry. This paper provides insight into some of the results that have been achieved in this work.

MORPHOLOGY AND CHEMICAL COMPOSITION OF HARDWOODS

Compared to softwoods, hardwoods in general exhibit a more complex physical structure. While softwoods essentially consist of one type of fiber (the tracheid), hardwoods, in addition to containing normal libriform cells, contain a larger proportion of parenchyma cells plus a rather high weight proportion of short but large-diameter vessel elements. The main purpose of these vessel elements is to transport water rapidly through the wood structure to the crown of the tree during the short growing season. Furthermore, hardwood fibers are significantly shorter than softwood fibers (Table 2). The two types of fibers thus have different aspect ratios, and this will result in generally improved forming characteristics for hardwood fibers during the papermaking process.

Hardwoods and softwoods differ considerably, not only in terms of morphology but also in terms of chemical composition; hardwoods in general contain significantly lower amounts of lignin and correspondingly higher levels of cellulose and hemicellulose than softwoods. Futhermore, the manner in which the lignin is distributed within the middle lamella and into the cell wall also differs between hardwoods and softwoods. In softwoods, the concentration of lignin in the middle lamella is about 73%, while that in the cell wall is 13%. In hardwoods, the lignin concentration is higher in the middle lamella and lower in the cell wall, with a more clearly defined transition zone. In addition, hardwoods have a higher hemicellulose content. In softwoods, the more pronounced lignification of the cell wall restricts swelling in the presence of alkali to a greater extent than in hardwoods, implying that different approaches may be necessary for the optimization of quality in the high-yield pulping of softwoods and hardwoods.

In the case of hardwoods, chemical impregnation is normally carried out using stronger alkaline conditions in order to take advantage of cell wall swelling, thus making the fibers more amenable to subsequent refining treatment. After chemical impregnation, preheating is normally done under atmospheric conditions to prevent caustic darkening and to minimize specific energy consumption. Chemical impregnation reduces the softening temperature of the lignin, and therefore it is important to have a relatively low chip temperature at the beginning of the refining process in order to facilitate rupture in the fiber wall.

HIGH-YIELD PULPING OF ASPEN

Physical property profiles for various high-yield pulps from North American aspen (*Populus tremuloides*) are shown in Table 3. These pulps were produced by impregnating aspen chips with a constant amount of

[1] Woodbridge, Reed and Associates. 1982. Market mechanical and chemimechanical pulp: a growth opportunity for Canada. Vancouver, B.C.

Table 1. Summary of Canadian incremental fiber supply, 1982 (millions of cubic metres per year)

	Softwood					Hardwood				
	Spruce	Pine	Fir	Other	Total	Poplar	Birch	Maple	Other	Total
British Columbia	0.78	0.37	0.27	0.41	1.83[a]	2.25	n.s.	n.s.	n.s.	2.25
Alberta	3.07	2.47	0.16	n.s.	5.70	9.25[b]	—	—	n.s.	9.25
Saskatchewan	0.37	0.47	0.02	n.s.	0.86	2.75	n.s.	n.s.	n.s.	2.75
Manitoba	1.19	0.76	0.04	0.01	2.00	1.44	0.15	—	0.01	1.60
Ontario	4.07	0.56	0.74	0.42	5.79	2.37	1.94	—	0.22	4.53
Quebec	4.08	1.30	(c)	0.93	6.31	2.83	5.10	2.41	0.70	11.04
Maritimes	0.00	0.00	0.00	0.00	0.00	0.10	0.23	0.47	0.10	0.90
Newfoundland	0.00	0.00	0.00	0.00	0.00	—	—	—	—	n.s.
Total	13.56	5.93	1.23	1.77	22.49	20.99	7.42	2.88	1.03	32.32
Percent	24.7	10.8	2.2	3.2	41.0	38.3	13.5	5.3	1.9	59.0

[a] By-product chips and pulpwood.
[b] Includes a small volume of birch.
[c] Included with spruce.

Table 2. Morphological characteristics of selected North American hardwoods and softwoods

Wood species	Fiber length, L (mm)	Fiber diameter, D (μm)	Large vessel diameter (μm)	Cell wall thickness (μm)	Aspect ratio (L/D)	Basic density (kg/m³)
Hardwoods						
Trembling aspen (*Populus tremuloides*)	1.1	10–27	95–100	2.5	40–110	352
Yellow birch (*Betula lutea*)	1.5	20–36	60–160	3.0	42–75	545
Sugar maple (*Acer saccharum*)	0.8	16–30	70–90	1.7	27–50	560
Softwoods						
Black spruce (*Picea mariana*)	3.5	25–30	—	2.2	116–140	400
Western hemlock (*Thuga heterophylla*)	3.6	30–40	—	3.3	90–120	384
Loblolly pine (*Pinus taeda*)	3.6	35–45	—	3.5	80–103	464

Table 3. Pulp quality characteristics of unbleached thermomechanical pulp (TMP) and chemithermomechanical pulp (CTMP) from aspen (*Populus tremuloides*)

	TMP	CTMP			
Impregnation conditions					
Sodium sulfite (kg/t)	0	20	20	20	20
Sodium hydroxide (kg/t)	0	12	20	40	50
Preheating conditions					
Temperature (°C)	125	103	103	103	103
Retention time (min)	5	5	5	5	5
Yield (%)	96.2	92.5	92.1	89.2	86.5
Freeness, CSF[a] (mL)	100	100	100	100	100
Shive content (%)	0.50	0.20	0.15	0.14	0.06
Density (kg/m^3)	365	409	440	545	600
Burst index ($kPa \cdot m^2 \cdot g^{-1}$)	0.90	1.60	2.00	2.60	3.10
Tensile index ($N \cdot m \cdot g^{-1}$)	23.0	39.0	43.0	51.0	60.0
Tear index ($mN \cdot m^2 \cdot g^{-1}$)	3.1	4.6	5.3	6.2	6.7
Brightness, ISO[b] (%)	58.0	61.0	58.0	49.5	44.5
Scattering coefficient (m^2/kg)	68.0	52.0	47.0	41.0	34.5

[a] CSF = Canadian standard of freeness.
[b] ISO = International Standards Organization.

sodium sulfite (20 kg/t) and different amounts of sodium hydroxide (12–50 kg/t). The impregnated chips were then preheated at 103°C for 5 minutes prior to a two-stage refining treatment.

Without chemical impregnation, aspen thermomechanical pulp (TMP), despite its high specific energy requirement, exhibits physical properties that are inferior in most respects to those exhibited by stone groundwood produced from softwoods. On the other hand, the optical properties of aspen TMP are impressive, the pulp having scattering coefficient and opacity levels that are well in line with those exhibited by typical stone groundwood at equivalent levels of drainage.

A mild chemical impregnation of aspen chips using 20 kg/t sodium sulfite and 20 kg/t sodium hydroxide prior to preheating and refining improves pulp quality to the point where it is comparable in optical properties and most strength properties to TMP produced from softwood chips to an equivalent level of drainage. The lower fiber length of the aspen, however, while it improves formation and density characteristics, results in low tear strength, equivalent to that of stone groundwood. Further increases in the chemical impregnation levels result in additional quality changes as indicated in Table 3, which manifest themselves in terms of decreased shive content and improvements in density and bonding properties, but only at the expense of reduced scattering coefficient and opacity.

RESPONSE OF ASPEN TO PEROXIDE BLEACHING

The response of aspen TMP and chemithermomechanical pulp (CTMP) to peroxide bleaching was evaluated. The TMP had a yield level of 96.2%, and the two CTMP samples at unbleached yield levels of 92.5% and 89.2% were produced by impregnating chips with 12 kg/t and 40 kg/t sodium hydroxide, respectively, at a constant sodium sulfite application level of 20 kg/t.

The effect of bleaching on the optical and strength properties of the three pulps is shown in Table 4. At unbleached yield levels in excess of 90%, aspen CTMP can be readily bleached to a brightness level of 80%. At unbleached yield levels below 90%, the relatively severe sodium hydroxide treatment involved in the impregnation stage reduces the unbleached brightness to 50% or lower, and this has a strong influence on the ultimately attainable bleached brightness. It is also evident that peroxide bleaching has the anticipated positive effect on the physical properties of the pulp and that bleached pulps generally exhibit improved density and bonding properties compared to the unbleached pulps (Table 4).

Table 4. Response of aspen thermomechanical pulp (TMP) and chemithermomechanical pulp (CTMP) to peroxide bleaching

	TMP				CTMP							
Unbleached yield (%)	96.2				92.5				89.2			
Peroxide (kg/t)	0	10	20	40	0	10	20	40	0	10	20	40
Freeness, CSF[a] (mL)	115	115	110	112	92	76	74	68	165	160	158	160
Density (kg/m³)	348	369	385	391	421	437	463	485	510	532	546	562
Burst index ($kPa{\cdot}m^2{\cdot}g^{-1}$)	0.71	0.75	0.90	0.96	1.76	1.81	2.17	2.33	2.12	2.31	2.48	2.73
Tensile index ($N{\cdot}m{\cdot}g^{-1}$)	26.0	28.0	28.2	29.2	40.7	43.7	47.2	51.2	47.9	49.3	51.0	55.3
Tear index ($mN{\cdot}m^2{\cdot}g^{-1}$)	2.8	2.7	3.3	3.1	4.7	5.0	5.6	5.5	5.9	6.8	6.2	6.2
Brightness, ISO[b] (%)	59.5	70.0	73.5	75.7	60.5	72.5	75.0	77.5	51.0	61.0	63.5	67.5
Opacity (%)	96.5	92.0	90.1	90.0	92.0	86.0	84.5	82.5	90.0	83.5	81.0	78.5
Light scattering coefficient (m^2/kg)	68.5	65.5	64.5	64.5	53.0	50.5	49.0	45.5	40.0	37.5	36.0	34.5
Light absorption coefficient (m^2/kg)	9.2	4.4	3.2	2.8	6.8	2.7	2.1	1.5	9.7	4.7	3.9	2.8
Brightness, ISO[b] (cold disintegrated) (%)	60.0	73.0	76.9	79.7	65.2	75.5	78.2	80.6	49.0	57.7	62.3	66.6

[a] CSF = Canadian standard of freeness.
[b] ISO = International Standards Organization.

These bleaching studies were carried out on pulps produced in a series of pilot plant trials. To substantiate these data, laboratory bleaching tests were also carried out on aspen CTMP produced in a commercial operation. Aspen CTMP, produced by impregnating chips with 2% sodium sulfite and 1.5% sodium hydroxide prior to preheating and refining, was bleached in the laboratory to 75, 80, and 85% ISO (International Standards Organization) brightness in a single-stage bleaching operation using 12, 20, and 45 kg of peroxide per oven-dried metric tonne, respectively, with bleaching involving a 2-h retention time at 10% consistency. By modifying the system to a two-stage operation with recycling of residual peroxide to the primary bleaching stage, the peroxide requirements to achieve the same levels of brightness were reduced to 10, 13, and 32 kg of peroxide per oven-dried metric tonne, respectively.

EFFECT OF ASPEN WOOD QUALITY ON PULP QUALITY

The trials discussed above were conducted on good quality aspen chips exhibiting no visible signs of decay. Because most hardwood stands contain trees exhibiting a wide quality spectrum, from clear undamaged specimens to specimens showing signs of advanced decay, an attempt was made to evaluate the effect of wood quality on resulting pulp quality.

Aspen logs from a particular aspen stand in Canada were thus sampled and segregated into four different wood quality classes. This classification was based on the visual appearance of the butt ends with respect to stain and decay. The four classes were clear logs, stained logs, logs showing visible signs of incipient decay, and logs showing obvious signs of advanced decay.

After chipping and screening, CTMP was produced from each quality class by impregnating chips with 2.8% sodium sulfite and 2.8% sodium hydroxide prior to preheating (103°C for 5 minutes) and two-stage refining. Resulting pulp quality data for pulps covering the freeness range 60–200 mL CSF (Canadian standard of freeness) are given in Table 5. It is evident that the most obvious effect of increased level of decay in the chips is a decrease in the brightness level of the CTMP, the clear aspen exhibiting a brightness level of 57% and that showing advanced decay having a brightness level as low as 40%. The two intermediate qualities of stained wood and wood showing signs of incipient decay had brightness levels of 49% and 45%, respectively.

With regard to mechanical properties, CTMP produced from clear and stained aspen exhibited better consolidation and bonding properties at a given level of drainage than did wood showing signs of incipient and advanced levels of decay, the latter quality resulting in the lowest CTMP quality, as anticipated. This quality of pulp also exhibited poor tear strength due to its lower long fiber content compared to the pulps produced from the better-quality chips. It is also evident that pulp yield is related directly to the level of decay (Table 5). The yield levels shown in parenthesis in Table 5 include the combined effects of fines loss on chip screening and yield loss across the CTMP pulping operation.

Laboratory bleaching studies were carried out on the various CTMP qualities referred to above (Table 5), and the bleaching responses of the various pulps are shown in Table 6. It is evident that the unbleached brightness differences noted among the various wood qualities persist, as anticipated, through the bleaching process. Thus, while the CTMP produced from clear aspen showed a brightness increase from 61.0% to 75.6% at 2% peroxide application, the CTMP produced from chips displaying signs of advanced decay exhibited a brightness improvement from 42.7% to 63.8%. For any given plant, starting wood quality will have an extremely strong influence on final brightness. Thus, for a multiproduct mill, high grading of chips may represent an essential feature of mill design.

HIGH-YIELD PULPING OF BIRCH

Initial studies were carried out on Scandinavian birch (*Betula verrucosa*). The system employed was relatively simple. It involved cold impregnation with different combinations of sodium hydroxide and sodium sulfite, accomplished by the overnight soaking of chips in liquor of suitable chemical composition. The impregnated chips were subsequently preheated for 3 minutes at 135°C prior to the single-stage refining to freeness levels in the range of 100–400 mL CSF. From the results (Table 7), it is evident that pulp quality is directly related to severity of the chemical treatment. Low chemical application levels resulted in high scattering coefficients and poor development of bonding properties, despite high specific energy application to attain a given level of drainage. Increased chemical impregnation levels, as anticipated, resulted in improved strength levels and decreased scattering coefficient and opacity. The effect of increased levels of sodium hydroxide decreased the specific energy consumption necessary to attain a given level of drainage.

Concerning the use of birch CTMP in printing grades, an acceptable combination of strength and optical properties requires the use of 2.5–3.5% sodium

Table 5. Effect of rot on aspen quality

	Clear aspen			Stained aspen			Incipient decay			Advanced decay		
NaOH (%)		2.8			2.8			2.8			2.8	
Na_2SO_3 (%)		2.8			2.8			2.8			2.7	
Yield (%)		88.7 (86.5)[a]			88.0 (85.2)[a]			89.2 (85.4)[a]			89.2 (83.4)[a]	
Freeness, CSF[b] (mL)	170	120	67	162	123	78	192	132	72	144	108	88
Specific energy ($kW \cdot h \cdot t^{-1}$)	620	1840	2300	1505	1670	1815	1535	1825	2160	1775	1935	2000
Density (kg/m^3)	389	404	444	361	388	450	328	358	410	358	385	376
Burst index ($kPa \cdot m^2 \cdot g^{-1}$)	1.42	1.81	2.19	1.12	1.49	2.12	1.07	1.27	1.85	1.15	1.29	1.33
Tensile index ($N \cdot m \cdot g^{-1}$)	37.3	41.7	48.5	36.5	42.2	48.2	29.6	32.5	45.1	32.6	36.7	36.7
Tear index ($mN \cdot m^2 \cdot g^{-1}$)	4.9	4.9	5.1	5.8	5.6	5.5	5.7	5.0	4.9	3.9	3.7	3.9
Brightness, ISO[c] (%)	57.0	56.5	56.5	48.5	49.0	48.0	45.0	46.5	45.0	40.0	40.5	40.0
Light scattering coefficient (m^2/kg)	46.0	48.5	48.0	41.5	41.0	44.5	40.0	44.0	44.5	44.0	47.0	45.5
Light absorption coefficient (m^2/kg)	7.4	8.1	7.4	10.9	10.3	11.6	11.4	11.9	14.6	16.6	17.0	14.5

[a] Adjusted yield for fines loss on chip screening.
[b] CSF = Canadian standard of freeness.
[c] ISO = International Standards Organization.

Table 6. Peroxide bleaching of aspen chemithermomechanical pulp produced from chips exhibiting increasing rot content

Raw material	Unbleached pulp yield[a] (%)	H_2O_2 (kg/t)	NaOH (kg/t)	Na_2SiO_3 (kg/t)	DTPA[b] (kg/t)	Residual H_2O_2 (kg/t)	Final pH	Brightness (%)	COD[c] (kg/t)
Clear aspen	86.5	Unbleached						61.0	166
		10	10	40	5	3.1	8.9	72.2	192
		20	15	40	5	7.7	9.2	75.6	198
		40	20	40	5	21.5	9.4	78.2	215
Stained aspen	85.2	Unbleached						52.9	177
		10	10	40	5	1.2	9.1	59.7	198
		20	15	40	5	5.9	9.2	67.2	212
		40	20	40	5	17.7	9.4	70.3	217
Incipient decayed aspen	85.4	Unbleached						50.2	158
		10	10	40	5	0.8	8.9	59.5	182
		20	15	40	5	3.2	8.9	65.2	189
		40	20	40	5	9.7	9.0	71.1	197
Advanced decayed aspen	83.4	Unbleached						42.7	157
		10	10	40	5	1.1	9.1	51.1	183
		20	15	40	5	5.0	8.6	63.8	190
		40	20	40	5	10.7	8.9	66.4	199

[a] Pulp yield includes fines loss on chip screening.
[b] DTPA = sodium diethylenetriamine pentaacetate.
[c] COD = chemical oxygen demand.

Table 7. **Effect of chemical impregnation level on physical properties of unbleached chemithermomechanical pulp from Scandinavian birch (*Betula verrucosa*)**

Sodium sulfite (kg/t)	10	10	15	12	40	27
Sodium hydroxide (kg/t)	10	24	30	40	40	44
Preheater temperature (°C)	135	135	135	135	135	135
Preheater time (min)	3.0	3.0	3.0	3.0	3.0	3.0
Yield (%)	95	94	93	92	90	87
Specific energy (kW·h per ADMT)	1650	1380	1120	1180	1020	920
Freeness, CSF[a] (mL)	100	100	100	100	100	100
Shive content (%)	0.30	0.25	0.27	0.30	0.20	0.20
Apparent density (kg/m^3)	270	342	360	378	450	468
Tensile index ($N \cdot m \cdot g^{-1}$)	11.0	30.8	35.2	39.6	51.7	52.8
Tear index ($mN \cdot m^2 \cdot g^{-1}$)	4.0	4.0	4.1	4.8	6.0	6.1
Light scattering coefficient (m^2/kg)	57.5	54.0	50.5	48.3	42.5	41.4
Brightness, ISO[b] (%)	55.0	52.0	53.0	50.0	50.0	48.0

a CSF = Canadian standard of freeness.
b ISO = International Standards Organization.

hydroxide in conjunction with sodium sulfite in the range of 1–2%. Higher strength properties can be obtained by increasing the chemical application levels, but only at the expense of reduced scattering coefficient and brightness. Conversely, at lower chemical application levels, light scattering coefficient improves but strength properties become inadequate.

For linerboard and similar applications, high density and strength are of prime concern and higher chemical applications are necessary. Specific energy requirements at these lower yield levels are correspondingly lower.

In conjunction with these trials, peroxide bleaching studies were also carried out. Brightness levels of 70% ISO brightness were readily obtained at economical peroxide consumption levels. With adequate washing, these studies also indicated that brightness levels of 80% were also attainable.

RECENT STUDIES

Recent investigations with hardwoods have indicated that significant advantages in process economics can be gained by dispensing with a pressurized preheater and maintaining the temperature of the impregnated chips below 100°C prior to refining. The main effect observed is a decrease in specific energy consumption to attain a given level of drainage, but the approach is also beneficial to pulp brightness.

Pulp quality data for unbleached CTMP from aspen (*Populus tremuloides*), yellow birch (*Betula lutea*), and sugar maple (*Acer saccharum*) are shown in Table 8, which also provides corresponding pulp quality profiles for these same pulps bleached with hydrogen peroxide to the brightness range of 78–80% ISO brightness.

For all three wood species, the CTMP was produced by impregnating the chips with 25 kg/t sodium sulfite and 30 kg/t sodium hydroxide prior to retention at 50°C and subsequent two-stage refining. Recognizing the large difference in basic wood density between aspen (360 kg/m^3) and birch and maple (540–560 kg/m^3), a retention time of 15 minutes was used for the aspen chips. This time was extended to 25 minutes for the impregnated birch and maple chips.

Under the impregnation conditions employed in these trials, the aspen CTMP exhibited superior density and bonding properties compared to the birch CTMP, and this in turn was superior to the maple CTMP. Furthermore, the significantly lower average fiber length of maple (0.8 mm), compared to aspen (1.10 mm) and yellow birch (1.5 mm), had a direct effect on the tear

Table 8. Pulp quality characteristics of unbleached and bleached chemithermomechanical pulp[a] from North American hardwoods[b]

	Trembling aspen		Yellow birch		Sugar maple	
	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached
Yield (%)	91.8	—	90.1	—	89.6	—
Specific energy ($kW \cdot h \cdot t^{-1}$)	1290	—	850	—	1000	—
Freeness, CSF[c] (mL)	105	100	105	100	105	100
Density (kg/m^3)	515	630	370	500	345	437
Burst index ($kPa \cdot m^2 \cdot g^{-1}$)	2.70	4.16	1.80	2.90	0.71	1.26
Tensile index ($N \cdot m \cdot g^{-1}$)	54	70	39	58	25	36
Tear index ($mN \cdot m^2 \cdot g^{-1}$)	6.3	6.9	6.2	7.1	3.1	4.0
Brightness, ISO[d] (%)	58.5	78.0	47.0	80.3	43.0	81.0
Opacity (%)	88.5	72.0	91.6	72.9	96.6	79.0
Light scattering coefficient (m^2/kg)	36.7	27.8	34.5	29.7	41.8	41.4
Bleaching chemicals (kg/t)						
Peroxide application	—	60	—	60	—	60
Peroxide consumption	—	29	—	35	—	36
Sodium hydroxide	—	40	—	40	—	40
Sodium silicate	—	30	—	30	—	30
DTPA[e]	—	30	—	3	—	3

[a] All unbleached pulps produced using impregnation conditions involving 25 kg/t sodium sulfite and 30 kg/t sodium hydroxide.
[b] Preheating conditions involved atmospheric preheating at 50°C for 15 min (aspen) and 50°C for 25 min (birch and maple).
[c] CSF = Canadian standard of freeness.
[d] ISO = International Standards Organization.
[e] DTPA = sodium diethylenetriamine pentaacetate.

strength characteristics, with maple CTMP exhibiting significantly lower tear strength than CTMP from either aspen or birch chips.

Peroxide bleaching to high brightness levels in the range of 78–81% ISO brightness also resulted in significant improvements in density and bonding properties but only at the expense of light scattering coefficient and opacity (Table 8).

At a given level of chemical application, birch and maple showed a poorer response than aspen to CTMP treatment. The treatment conditions, however, can be adjusted within a relatively broad range to produce a physical property profile suitable for a particular end use application of the pulp. This has already been demonstrated for aspen by the data shown for different chemical treatments and consequently different yield levels in Table 3. Similar effects for CTMP from birch and maple chips are shown in Table 9, which summarizes pulp quality at 105 mL CSF for two different chemical application levels for each of the two wood species.

CONCLUDING REMARKS

In North America as well as in Europe, hardwoods currently represent an underutilized source of raw material for the pulp and paper industry. For the continued well-being and future expansion of the North American industry, serious attempts must be made to use the available hardwoods. The process technology required for the production of high-yield pulp from major Canadian hardwood species is currently available. Furthermore, this process is capable of producing pulps with a combination of mechanical and optical properties suitable for use in a wide range of printing and writing papers. Raw material quality has been identified as an important parameter, because decayed wood results in pulps of inferior strength and brightness compared to pulps produced from sound wood.

Table 9. The effect of chemical treatment on chemithermomechanical pulp from yellow birch and sugar maple

	Yellow birch		Sugar maple	
Sodium sulfite (kg/t)	25	25	25	25
Sodium hydroxide (kg/t)	30	50	30	50
Yield (%)	90.1	88.8	89.6	88.6
Specific energy ($kW{\cdot}h{\cdot}t^{-1}$)	850	800	1000	910
Freeness, CSF[a] (mL)	105	105	105	105
Density (kg/m^3)	370	495	345	456
Burst index ($kPa{\cdot}m^2{\cdot}g^{-1}$)	1.80	2.60	0.70	1.40
Tensile index ($N{\cdot}m{\cdot}g^{-1}$)	39.0	54.0	25.0	35.0
Tear index ($mN{\cdot}m^2{\cdot}g^{-1}$)	6.2	6.7	3.1	3.9
Brightness, ISO[b] (%)	47.0	38.5	43.0	40.0
Opacity (%)	91.6	89.5	96.6	94.6
Light scattering coefficient (m^2/kg)	34.5	25.8	41.8	38.8

[a] CSF = Canadian standard of freeness.
[b] ISO = International Standards Organization.

SECONDARY MANUFACTURING CONSIDERATIONS

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My purpose today is to take you on a journey outside of the pleasant and serene forest, beyond the smell of pine needles and rat-a-tat-tat of the woodpecker, and into what I will call the real world.

The real world in this context is the place where forest products are consumed, or not consumed, where customers make decisions about whether to use wood or aluminum windows, wood or vinyl siding, wood or concrete and steel structures. The real world has become a place of concrete and steel, of aluminum and vinyl. Increasingly for the past 25 years, the forest products sector has been losing markets and market share to these other materials. Gone are the days when the requirement for shelter automatically resulted in the decision to go out into the forest, murder a few trees, and haul them back to your building site.

Competitors to the forest products industry have done a real number on forest products. They have pointed out to the customer that wood has a number of disadvantages. They have told people that wood burns, it rots, it twists, and it swells. They have managed to get the concept of noncombustible construction into the building code in order to exclude wood from large buildings.

While this was happening, the forest products industry was sitting back smelling the pine needles and listening to the rat-a-tat-tat of the woodpecker. The industry agreed that wood burns; that is obvious, because we have forest fires. It did not bother to point out that, in a fire, steel melts, concrete crumbles, and plastics give off some very noxious fumes or that wood can be protected from fire by application of gypsum. It did not talk up the beauty of wood, its workability and versatility, or its natural resilience in earthquakes. In other words, it fumbled the ball and allowed these other materials to grab the customer.

As I see it, one of the major reasons for this is that the primary producers have been driven by the concerns of production and forest management rather than by the needs and concerns of the customer. The forest is far from the cities where the customers are. Indeed, it is a more pleasant place to be. So rather than going to visit the customers to find out their concerns, the producers preferred to let the wholesalers do the selling while they produced what they wanted to produce—and took whatever price that would bring. The best route to making a profit was to become more efficient at murdering trees.

The wholesalers also rarely bothered to go see a customer; they seemed to prefer to sit in their offices and look at the nice scenes out their windows while they bought and sold over the telephone. On the rare occasions when they saw a customer, it was to meet him for lunch at a fancy restaurant; rarely did they visit his manufacturing plant or dare to discuss the concerns and problems they were having with forest products. Thus, the primary producer was not getting good feedback from the customer. The game became high volume at low prices and maximized yield, not value. This is what I call the producer mentality.

One good example of the producer mentality, and the emphasis on yield rather than value, comes from the machine stress rating (MSR) industry. Machine stress rating of lumber is an excellent way of sorting lumber according to its strength. Logically, the stronger lumber should command a better price and, also logically, the customers for MSR lumber would be largely the truss fabricators. Unfortunately, the producer mentality abounded when the grading rules were written, and the truss industry was not given adequate input. The grading rules permitted No. 2 wane on lumber destined for the highest performance application in trusses—trusses that were connected by light metal truss plates. Because the cross-sectional area of the member is important in the calculation of a high-performance truss, an engineer cannot overlook the cross-sectional area that could be missing due to the No. 2 grade wane. Even more important is that the teeth on the metal truss plates are only about 3/8-in. long, so any teeth in the wane area are not effective. This can have a very serious impact on the strength of the truss. As a result, the MSR producers eventually discovered that the truss fabricators did not want to pay them high prices for MSR lumber with No. 2 wane or, worse yet, did not want to buy it at any price. This whole problem could have been avoided if foresters had learned how to grow square trees!

Another way this problem could have been avoided is if the customer had been consulted or considered while the grading rules were being written. The silly part of this story is that the grading rules still have not been changed. The mills currently producing MSR lumber have learned how much wane they can get away with, but the problem keeps reappearing when they forget to train the new grader or when a new MSR mill comes on stream, factors that do not gain the confidence of the truss industry.

The producer mentality, combined with poor quality feedback from the wholesaler, probably resulted in the problems being compounded when the boss went off to the annual association meeting. Here he consistently voted to keep the dues down. After all, the association was not doing anything to improve his yield, productivity, or prices. These association guys were just a bunch of fat cats living on an expense account paid for by the dues. Thus the industry associations were deprived of the funds needed to carry out their logical mandate—to promote the market for forest products, to protect and enhance its position in the building code relative to other materials, and to support research and development as well as education.

These are very valid mandates, and the forest products industry has done little to support them, compared to other industries. If I have said anything so far that has annoyed you, then that is good! The steel and concrete industries have been leaning on the forest products industry far too long now. It is time for us to stake out our ground.

Consider the promotional campaign with an ad showing a fire raging in one room, while a child plays in the next room protected by a cement wall. These ads support the lobbying campaign to get the building code changed to your disadvantage. Consider the funding they have put into education to the extent that graduate engineers and architects think steel or concrete when designing any building bigger than a house.

If we want to stop the erosion of markets for forest products, we are going to have to imitate the steel, concrete, and plastics industries, and if we want to reverse the trend, it is going to cost some money.

But I think it can be done. In fact, I have noticed a change of mood in the past few years. I have noticed that our R & D organization, Forintek, has become much more responsive to industry needs because it now depends to a much greater extent on funding from industry rather than government. And I think industry is increasingly seeing the value of Forintek and its R & D efforts. The "In Grade Testing Program", the fire research, and the move to reliability-based design in the building codes are examples of programs that will yield positive results in the future and allow us to get forest products into larger buildings.

I also feel that there is a new mood in the Canadian Wood Council (CWC). I attended a CWC meeting a few weeks ago at which a panel of architects, engineers, and building officials was invited to tell council members what a lousy job they do on promotion and education. I think that is great! They have the problem identified.

Of course, identifying the problem and solving it are two different things. It takes money to increase efforts in promotion, lobbying, R & D, and education. One proposal put on the table at the CWC meeting was to hire 17 sales reps across Canada whose main activity would be to promote wood products with architects and engineers. If this proposal gets approved and funded, it will be a tremendous move forward. Not only will it take the forest industry's message to the design community, it can also be an alternate method of communicating the needs and concerns of the customer back to the producers so they can be addressed.

The issue of dues to support these activities would not be unlike the increase of dues necessary to fight the countervail duty issue. In the case of the countervail, the industry readily saw the danger and rallied to support an expensive lobby program to fight it. It was expensive, but unfortunately unsuccessful. When it was over, the dues were lowered. In my opinion it would been far better if the dues had been maintained and the funds redirected to efforts to increase the market share of forest products.

I am very pleased that the industry is recognizing its problems and doing something to help itself, and I am optimistic that those efforts will increase. I am also confident that those efforts will be rewarded. I speak from experience. My company has been doing many of the things that I have been advocating, and the rewards have been worthwhile. For 25 years we have supplied truss fabricators across Canada with truss plates and engineering services. In recent years we have improved the quality and quantity of printed promotional material. We have developed computer software that makes it possible to better analyze alternatives. We recently released a software package that enables truss and beam layouts to be done quickly and accurately for very complicated wood structures.

Also in recent years, we have embarked on a campaign of direct promotion with building designers. The program is supported by professional literature and videos, fire tests, and sound tests and is carried out by a dozen technical sales reps in cities across Canada. The products we are promoting are wood trusses, wood I-beams, Parallam and Westlam beams, and oriented strand board. After only a few years of this effort, we are seeing a 20% growth rate on truss connectors and an annual doubling of I-beams, and we have been unable to get enough Parallam to meet the demand. This increase in business is largely due to getting these products into buildings that a few years ago would have gone to noncombustible construction—buildings such as schools, strip shopping centers, walk-up offices, fast-food outlets, factories, and even one hospital.

Of course, the process of getting forest products specified is not just a matter of informing the specifiers that they are available. Hand in hand with that is a commitment to quality and reliability.

The industry must recognize that as we move forest products into buildings other than housing, the risks to public safety increase and along with that so does the liability of the producer. Products like Parallam and I-beams undergo very extensive quality control procedures at the plant and are probably more reliable than most forest products.

In our I-beam we utilize 2 × 4 MSR lumber, which we finger-join into long lengths. Our quality control program for finger joints includes tension proof testing. Because of this tension testing program, we discovered that the practices of most MSR mills were deficient when it came to the visual overrides on the knot sizes. We were breaking a high percentage of the lumber at locations away from the finger joints. The mills were initially slow to respond. They did not see why they should do something about it; after all, they could sell all of their MSR lumber in the U.S. to truss fabricators. Of course, that also scared the hell out of me, because we engineer half the trusses used in this country, and I know that a lot of them use MSR lumber in the bottom chords where the stresses are almost pure tension.

Obviously something had to be done to inform the mills of the problem as well as the critical end use. We initiated a study into the tension properties of MSR lumber with the assistance of the Canada-Alberta Forest Resource Development Agreement and in the process got the MSR mills and the grading agencies to tighten up quite a bit. I will not say the problem is gone yet and it is very easy to fall back on old ways. For this reason I continue to press for a change in the quality control requirements of MSR lumber to include tension testing as well as bending, so that the mills will have immediate feedback. This will be a significant step in improving the reliability and quality of our products, which is an absolutely essential part of the process of getting forest products into commercial- industrial buildings and stopping or reversing the decline in use of forest products.

There is a final point I wish to make, and this is probably a good place to make it because there are so many government people here. It has to do with the way statistics are gathered for the forest products industry. There is at present no separate category for the truss industry. I think we are lumped in with prefab homes or other. That makes it awfully difficult to convince the lumber producers that we are a significant consumer of forest products. If they were more aware, then they would be more responsive. I believe the truss industry in Canada consumes $200 million worth of lumber. I get that number because I know how many dollars worth of connector plates I sell, I know the usual ratio of connector plates to lumber, and I know pretty well what market share I have. If you follow the 10 to 1 rule, then the U.S. truss industry consumes $2 billion in lumber. If anyone in the audience is in a position to revise the way the consumption data are reported, it would be a tremendous help.

WOOD PRODUCTS MARKETING: CAN THE OLD DOG LEARN NEW TRICKS?

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INTRODUCTION

This presentation is not another exhausting explanation of a series of charts and diagrams based on lengthy marketing studies; we have not demographically dissected supply-and-demand factors in order to support our analytical descriptions of where the worldwide industry is headed based on the most current trends. The overmature, $30-billion-per-year forest industry in Canada does not need to deepen its dependence on more market studies. We do not have to reiterate the data—it is well known that 1987 was a record year for the industry as a whole. The average increase in earnings of the top two dozen North American producers last year was nearly 100%. Because of these earnings performances, the "old dog" we know as the wood products industry now has the opportunity to revitalize itself. It is time to quit relying on outside influences to generate innovation. This is the real need: the wood products industry must adapt itself for the "flatter" future ahead.

The title "Can the old dog learn new tricks?" is a revision of the adage "You can't teach an old dog new tricks." There is a distinct difference between learning and being taught; one is active, the other passive. The old dog must learn for himself. The new tricks under discussion also need clarification. I am not suggesting that the industry, in light of government grant programs, for example, learn a new way to sit up and beg; nor do I suggest that in the face of increased off-shore competition, we roll over, and I definitely am not saying that we have to play dead against decreasing resource prices.

The real new tricks relate to the need for the industry to integrate a parallel development philosophy related to the maximization of additional values for forest products. The time to learn these new tricks is now, and this presentation evaluates development philosophies as they relate to the need to adjust to new and existing marketplace demands. Several industry research and marketing groups have prepared reports over the past 2 years on the need for an attitude adjustment, and this discussion is in part based on an evaluation of these various perspectives.

The typical industry conference reminds me of the two individuals who were asked why a pot of water was boiling on the stove. The first one replied, "Energy is being applied in the form of heat, causing the atmospheric pressure in the liquid, interior to the vessel, to increase in juxtaposition to the atmospheric pressure exterior to the vessel. Hence, it boils." The second individual replied that the water was boiling on the stove because he wanted to have a cup of tea.

Both individuals are correct; they just need to get together on their objectives. Unfortunately, however, they symbolize what has become, for the forest products industry, a commonplace example of what could be called "jurisdictional chauvinism" between manufacturing and marketing. At the risk of sounding chauvinistic myself, it seems that the typical forester is, just as often as not, working in his own monodimensional position within the industry as a whole. Too often, mill management has to choose between the production manager's formula that $E + S + Q = (\$)$ (efficiency plus standardization plus quantity equals reduced costs) and the progressive marketing manager's philosophy that $D + I + C = V$ (diversification plus innovation plus confidence equals value). We need to be diversified in order to be open to new products and processes, innovative by not being afraid to try new things, and confident in other disciplines within the forest industry.

Traditional Practices

The timber industry is as ancient as creation itself; after God created the heavens and the earth, the skies, the seas, and the land, He planted trees. Indeed, even the garment business in the Garden of Eden was based on the fig tree. More recently, the Industrial Revolution imposed mechanized standards on virtually every aspect of developing society, and those original standards, based on original sawn lumber dimensions, continue to dictate production practices today.

Accordingly, mills utilizing wood fibers have become more and more super-efficient in order to reduce costs, increase volumes, and maintain market share. But in the process of reducing costs, such mills run the risk of creating another cost, the cost of becoming totally inflexible. Mills are now expert at manufacturing only one product (usually a high-volume, low-margin commodity item) and cannot produce anything else. And they dare not change; unit costs demand volume throughout. This is the traditional practice of the wood products industry. In a perfect world, it would be the best way. But we do not live in a perfect world, and innovative solutions are needed.

Innovative Solutions

In a recent address to the International Particleboard Symposium, Peter Drake of Woodbridge, Reed & Associates of Vancouver stated that "Any change from basic commodity production will be successful only if there are fundamental changes in (the)... philosophy (of production, marketing, and management). The company must change from a *volume* approach to a *value* approach... The technology already exists to develop many value-added options. ***What is lacking is the confidence to pursue them.***"

Plant managements must begin to define their total operations in terms of adding more value, not just adding more output. This requires the producer to develop the market know-how and production technology to influence the stability of those secondary enterprises that use, and that depend on, wood products. The forester must also understand these markets and match timber management plans accordingly. This proposal further implies that the producer has a thorough understanding of the needs of his clients. More will be said of this later.

THE CHALLENGE TO SURVIVE

While it may sound simplistic to suggest that all we need is more value, the point cannot be overemphasized. Every area of wood processing, from the forest to finished furniture, is open to enhanced practices, and every area that has already benefited from new ideas and methodology should never be allowed to stagnate at that level. In the wood business, the only thing that stays the same is that things never stay the same! Nor should they.

The foundational premise here is that progress is essential to survival. If we accept this premise, then it stands to reason that progress in all aspects of the industry should not only increase the survival rate of processors but should also expand the quality of their industrial health.

In order to add value to the entire operation, the challenge to the wood products processor is to evaluate all areas to achieve a "saturation of integration". In general terms, this type of development integration refers to the parallel and progressive development of all key elements needed to define and implement a given project. This is the key point of this presentation. Essentially, this may involve several operations, including the whole technical arena (involving R & D, product development, and engineering), as well as marketing, financial planning, material sourcing, and supply management. The important factor is that all areas need to be integrated simultaneously into the development process. To correlate and cross-correlate every component at each phase might not guarantee final success, but it will most certainly ensure that problems will be identified before they become insurmountable obstacles.

A recent plastics manufacturing project is a prime example. The prototypes for this exciting new concept captured the imaginations and the pocketbooks of private investors and governments alike, and millions of dollars were injected to launch the project. A plant was built, specialized equipment was imported and installed, and production molds were undergoing final design and fabrication. While all this was being done, the corporate management team—a bunch of marketing types—were running wild with multimedia promotions. Their superb efforts brought in presold orders for carloads of product. Unfortunately, by the time engineering began to catch up with marketing, it became evident that what had been sold could not be manufactured, and so the company failed.

A second illustration is the case of the research labs we have all heard of, where new products or processes have been designed and developed to an advanced state of technical worth, only to sit on the shelf for years—or maybe forever—because no markets were ever identified or developed for the product. In such cases, by the time marketing catches up with engineering, what can be made cannot be sold.

In a more specific look at the challenges to survival, three main sectors will be assessed: technical challenges, political challenges, and marketing challenges.

Technical Challenges

The challenges related to technical opportunities involve both those associated with raw material supply and those affecting the manufacturing process itself.

The supply of fiber for the wood products industry is both renewable and exhaustible, meaning it will not last if it is not properly cared for. The life of the industry depends on its superior management abilities to sustain and expand present yields. This may involve a total reversal of traditional planning; it certainly will demand a region-by-region focus. The key to this focus for future growth in timber planning must be founded on a thorough understanding of fiber marketability. If sustainable market opportunities can be identified for specific products from a particular species, then future planning focusing on that species should reflect adequate exploitation, without degeneration of the stock. Clearly, the challenge here is to forecast the species that will portray the maximum value in the year 2060.

Alberta's lodgepole pine is an example of an undermarketed species. Clear value-added opportunities exist for lodgepole furniture wood and pine paneling, in addition to the tree's use for treated lumber. Such opportunities will not be properly exploited if lodgepole remains comfortably categorized in the traditional spruce–pine–fir sector.

An example from overseas is the plantation management of radiata pine in New Zealand, known as Monterey pine in California. Through genetic improvements, this common, temperate-zone pine species reaches maturity in 25–30 years in New Zealand, one-third the time needed in California. Radiata plantations will likely be supplying much of the raw materials for the developing Asian industry, where this specific species will bring new value to specific pine products.

Italy's experience with hybrid poplar also demonstrates the benefits of responding to the challenge of raw material development. One of the world's fastest growing plantations in the Po Valley area has spawned 80 plywood mills, with hybrid poplar being grown to peeler quality in as little as 10 years. By using a specific product—poplar plywood—to drive the development of a specific species, new value has been added to the forest for the sustainable benefit of an entire region. Obviously, there is an added cost to this type of plantation management, but the increased value of the total impact should justify the increased cost for delivered wood.

A further example of value-added fiber has to do with waste utilization. Studies conducted by Forintek Canada Corp. into the use of the whole tree, bark included, for waferboard production indicated that even with a drop in some properties, strength was still above Canadian Standards Association minimums. This alone can add up to 20% more fiber in some cases. Recent American studies into the use of juvenile hardwood species—2- to 3-year-old autumn olive, black locust, and sycamore plants—for oriented strand board (OSB) have certainly affected commercial viability of stems and branches. How much value is being left behind by the loggers as trash on the forest floor? Can some of this be economically recovered as suitable furnish? There has been some use recently of whole trees by the pulp industry as well. This is an area of timber management that cannot continue to be overlooked, given the increasing pressures on long-term wood supplies.

Keeping pace with technological developments in new equipment and processes is another real challenge to wood processors. Technology has now gone well beyond the simple use of a minicomputer to calculate utilization. How would you like to modify your plant to include full-axis scanners, proximity sensors, programmable indexing and sequencing operations, laser controllers, microwave dehumidification, hydraulic positioners, and digitized camera maintainers?

Roy L. Murphy, an industrial engineer from Hot Springs, Arkansas, has actually designed such a plant on paper and comments that future survival will be based on such technological incorporation. "Therefore," he writes, "the sawmill of the future must be a high-speed, high-yield, product-flexible, low-manpower, and high-production rate facility, if it is to be domestically, internationally, and globally competitive."

Such total-tech may not be necessary or even desirable in some situations. The challenge to today's producer in any industry is to gauge equipment capacity for maximum raw material utilization in order to optimize product value and marketability. It is unfortunate to see tight-ringed, first-growth, machine-stress-rated quality softwoods being diverted into studs just for the sake of maintaining throughput quotas.

As we consider plant facilities, the relationship among national, regional, and independent producers should be evaluated. Bigger is not always better. A study conducted last year by Forest Industries Magazine evaluated the shake-out in Oregon's lumber and plywood industries between 1977 and 1985. National plywood firms, accounting for less than 40% of the capacity, were responsible for over 50% of plant closures. This was one-third more than regional producers. Of the top lumber producers, production capacity shifted completely to the independent during the study period. Both national and large regional firms were too inflexible to adjust to new technology and management techniques and were too slow in reacting to market changes.

Not much has been reported on the growing focus of so-called mini-mills. We have had small, portable sawmills with us for decades, but in the past year or so, cost-efficient equipment packages are turning up for OSB and particleboard as well. Even S-pulp, using a recently debugged steam explosion technique, may be ready for commercialization. If these types of processes can become commercially acceptable, we may see real growth in reconstituted panel mills costing only a few million dollars, and whoever heard of a pulp mill for only $30 million? Economies of scale may no longer be as critical a consideration in plant design.

Suffice it to say that from a value-added perspective—on the basis that such a perspective is necessary to survival—high-tech or total-tech may not always be the solution, and bigger will definitely not always be better. What the real solution is will invariably be dictated by the marketplace.

Political Challenges

It may seem strange to sandwich political considerations itical issues. Without someone to buy wood products, between technical and marketing considerations, especially in a discussion on value-added opportunities, yet international influences affect every facet of the wood products industry, especially when the presumption is made that product marketability is the basis for survival.

Understanding and exploiting global trading trends is essential to every forest-producing sector, whether in pulp and paper, sawn lumber, reconstituted panels, or composite products. The increase in offshore shipments from North America in 1987 was 28%; forecast increases in 1988 indicate an average of 32%, with Japan claiming the highest volume at a 30% increase and Korea at 40%, China at 50%, Europe and the U.K. at 30%, and Australia at 35%.

The implications of global trading patterns make it imperative that the Canadian softwood- and hardwood-using industries keep abreast of international activities. With developments relating to the General Agreement on Tariffs and Trade (GATT) and with the clear benefits of the proposed Canada–U.S. free trade agreement, the two-way door is larger and opening wider. The temporary concerns of tariffs on Canadian softwoods and U.S. plywood should be quickly offset by the added benefits of increased market access not only for traditional wood products but, more importantly, also for a new generation of value-added specialty products.

Of major significance among the factors influencing Canada's wood-using industries is the rising Canadian dollar. Each one-cent increase in the dollar against its U.S. counterpart translates into tens of millions of dollars in lost earnings annually. With 74% of Canada's wood exports currently being shipped to the U.S., the need to continue developing off-shore markets is obvious.

Increased competition from foreign manufacturers can also not be ignored. Canada is not an importer of most wood products, but as developing countries continue to expand their industrial bases there is no question that timber products will form a major component of their expansion agendas. In no sector is this more true than in reconstituted panels. Given the overall pessimistic outlook for the world's timber future, waferboard and OSB-type products (as opposed to plywood) will become a more practical form of wood fiber utilization for applications in developing nations in Asia, Oceania, and Latin America. More and more, medium-density fiberboard is becoming the manufactured product of choice for green-field developments in the third world. Because the industrialized countries consume 70% of the worldwide production of wood-based panels while producing only 50%, the developing nations will be looking to increase exports in areas that will create competitive pressures on existing North American plants. Clearly, panel products of all kinds will be produced everywhere in the world by the mid-1990s.

As an aside to this particular issue, it should be noted that Canada's place as a world leader in certain wood technology carries with it a global responsibility. The provision of transferable technology to emerging nations should never be regarded as aiding and abetting the enemy. As these countries begin to build their own economies and demonstrate the global obligation to develop timber processing in a responsible manner, Canada can and should be involved. The desperate need for manufactured housing in developing nations, including large panels and modular systems, is a clear case for Canadian leadership. As Pope John Paul II has said, "Development demands, above all, a spirit of initiative from the countries who most need it" and, obviously, from those mature countries, like Canada, who can best provide the essential support.

Marketing Challenges

The challenges related to marketing concerns are of primary significance to the polor without a place to sell them, it makes little sense to produce anything in the first place. We would be, in fact as well as in adage, simply hewers of wood.

Traditionally, innovation has come to the industry from outside. I will not detail the history of all the standard wood products that now form a basic part of the industry, but the time has come for the wood products profession to do for itself what others have traditionally accomplished. Innovation should come from a new breed of nontraditional marketeers who are prepared to challenge the rules in order to create higher value-added products and services.

John Kelly of Weyerhaeuser Corporation, in speaking on the topic of really knowing our customers, listed several comparisons between those salespeople who have a "look out" attitude and those new marketing professionals whose philosophy is based on "looking outward". We should stop talking to our customers and begin listening to their concerns. If we only tell them what they can buy from us, instead of letting them tell us what they need, we only succeed in creating a confrontation between the mill and the customer. Plants should sell solutions, not products.

In this regard, Kelly suggests that when you are hiring new marketing personnel, do not spy on the competition to see who are hot and try to steal them away. Go to your own client list as a source of market representatives. By developing a thorough understanding of the needs of the marketplace, a more valuable product will result. Give customers what they want, not what executives think the customer needs. It may be as simple as providing a cut-to-size service to existing customers, in order to add value without adding much cost. Too often, secondary industries accept what they can get at the plant gate without question, because that is all the mill ever makes available. In order to survive, the industry must become more receptive and responsive to client requirements.

You are all familiar with the common kitchen fixture, the Pyrex measuring cup. It has been around, unchanged, for 50 years. Pyrex recently began listening to customer beefs about the cup: it did not stack and tended to boil over in the microwave. The company changed the design, made the cup deeper, and watched sales begin to soar. Another dramatic example is the Ford Motor Company, which developed a customer wish list of over 1400 desirable features for a new car. Ford incorporated over one-half of these items in the Taurus–Sable design, and in 1986, for the first time since 1924, Ford's profits beat those of General Motors.

At a symposium such as this, which has a timber focus, I probably should not say too much about nontimber sources of commercial fiber. Yet it should be noted that there are some traditional wood-based products that can and have been successfully manufactured using substitute materials. Essentially, wood is composed of cellulose fiber, which comes in many different forms. Agricultural residues such as wheat and barley straw, rice husks, and sugar cane bagasse are currently being used around the world to make particleboard. Flax-straw boards were the norm in Belgium for decades. Moss is being used in Quebec to make pulp. Illinois corncobs have been successfully used in the lab to make fiberboard. Though trees will likely never lose their place as the largest source of cellulose mass, alternative sources are commercially useful and should not be discounted as competitive fiber for certain applications. The positive side to this is that the same technology used to develop uses for agricultural residues is also showing the way to a more efficient use of wood materials.

THE MARKETPLACE FOR WOOD PRODUCTS

I would like to summarize quickly several existing and not-so-existing wood products.

"Real" Wood Products

SOLID WOOD: lumber, millwork, machine-stress-rated wood, beams, posts, spools, pallets, and chopsticks

RECONSTITUTED WOOD: plywood, waferboard, oriented strand board, particleboard, and medium-density fiberboard

Clearly, unless technology creates a new wave of cannibalism within the industry, the present-day products that enjoy a real place in the market are probably here to stay. Some products will be affected by fluctuating market share, however, as the quality and species of harvestable timber changes. Peeler logs will certainly affect the viability of plywood production, and the reduction of tight-ringed, first-growth softwoods will diminish the availability of machine-stress-rated lumber. Other products, such as chopsticks, are only now beginning to address their real potential.

Another "real" composite product should also be mentioned. For the pulp and paper industry, the development of the Tetra Pak has to be one of the most successful innovations in recent years. This combination of paper, plastic, and aluminum foil is now used for a wide variety of products, with over 30 billion units sold annually.

The growing use of reconstituted panels as a substrate for nonwood laminates is another significant area of growth.

"Realistic" Wood Products

STRUCTURAL COMPOSITES: laminated veneer lumber, Comply, Parallam, and aligned strand lumber

"BORN AGAIN" PRODUCTS: hardwood flooring and log homes

PULP AND PAPER: hardwood pulp (steam explosion)

The category labeled "realistic" refers to products that are now being manufactured but do not enjoy extensive consumer acceptance. This will change as processing and product benefits become more acceptable. The "born-again" products are already experiencing renewed market growth in some areas. Hardwood floors are now adding instant value and prestige to nearly one-quarter of North American homes. Sales of hardwood flooring have more than doubled since 1982. Log homes are now an annual one-half billion dollar industry, with hundreds of prefitted packages being shipped annually to Japan and over 1000 sold per year in Pennsylvania alone. One western Montana manufacturer, using computer-aided design techniques, is growing at the rate of 35% per year.

"Really?" Wood Products

SOLID WOOD: densification or polymerization

RECONSTITUTED WOOD: use of juvenile hardwoods, formed building blocks, and extruded cants

COMPOSITES: structural insulation panels and wood or glass fiber automotive panels

This last category is a kind of catch basin for assorted fantasies and visions that may or may not ever see the light of a commercial day. Some, however, have been successfully proven at the laboratory level. A wood polymerization pilot plant is being planned in New Brunswick, and General Motors has conducted aggressive research into the use of wood in composite automotive panels. Early tests indicate a product structurally comparable to engineered plastics can be produced at only 15% of the cost of plastics. The corrugated waferboard developed by the Alberta Research Council is another potential product.

Other potential product applications could be mentioned, many using existing products in new ways. Oriented strand board siding, reconstituted concrete forms, molded door panels, coffin components, cement-bonded panels, reconstituted railway ties, and in-board moisture, sound, and fire barriers are just a few new potential uses.

CONCLUSION

The real objective of this discussion has been to address the question of whether the old wood products dog can develop new ways to survive in the changing and challenging decades ahead. The real answer to this question can only come from within the industry itself. As long as trees continue to grow, it will be the responsibility and obligation of the tree-using industry to develop the maximum value out of each tree.

This can be accomplished in a more profitable and productive manner, and with maximum benefit to the health of the permanent commercial forest if every sector—forestry, production, and marketing—works in unison through parallel development toward common goals.

POLICY DEVELOPMENT NEEDS FOR SUCCESSFUL MIXEDWOOD MANAGEMENT

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INTRODUCTION

There are two impressive displays in the British Columbia Provincial Museum in Victoria. One is a replica of the coastal rain forest with its large tree trunks, underbrush, stuffed blacktail deer in openings, and a few birds in the branches—all very cleverly replicated. Through speakers come bird sounds to add to the realism.

The other is a replicated wooly mammoth, a huge creature in its diorama, standing in an expanse of arctic tundra. Some anthropologists postulate that early humans crossing over the Bering Strait led to the mammoth's extinction by overhunting it. It is interesting to imagine how those first hunters would have felt after killing that first one and viewing that immense, inert mountain of meat. The question in their minds was undoubtedly "Now what?"

This analogy came to mind near the end of this 2-day symposium that has presented so much meaty material. The question now is how to handle it. Ideally, we could set out to try to systematically take it apart. Because time does not permit, I propose to present a framework for analysis, discuss some of the issues that have been raised, and share a few philosophies.

FRAMEWORK FOR ANALYSIS

The word "policy" can mean many things to many people, ranging from the very specific to the general. It is important to consider policy in an inclusive sense comprised of three major components: goals, means, and process (Worrell 1970). Goals or objectives must define what we want to achieve. Means represent courses of action chosen to meet those goals and address the question of how to undertake action through programs, projects, practices, or approaches. Process is the administrative infrastructure necessary to ensure that the means are put into effect through the provision of funds, human resources, training and education, organization, supervision, control, and coordination.

These components represent a continuum, all elements of which must be in place for any policy to be effective. These components can be applied to the whole spectrum of interests expressed during the symposium, ranging from fundamental concerns about the forest through to finished product and customer satisfaction.

Implicit in each component is evaluation or assessment of the results. Three major questions must be addressed: were the actions effective in doing what was intended? Were they efficient in terms of return for the effort? Were their side effects desirable or undesirable? This question of evaluation is illustrated in Figure 1. An excellent example was presented by J. Drew in his evaluation of seedling survival, proving that it is an important step in fine-tuning the system as it develops and as results become evident.

Gordon Baskerville (1986) said much the same thing in his 1986 report on the audit of management of the crown forests of Ontario. He advised that

> For management to be effective, the plan should (i) contain a measurable and attainable objective, (ii) have an analysis of what features of the resource structure are preventing attainment of the objective, (iii) have a strategy for overcoming that limitation, (iv) have a program of implementation, (v) have measures of effectiveness for the implemented program, (vi) have a process of evaluating actual progress relative to the objective, and finally, (vii) establish a systematic periodic re-evaluation in which nonconformance of outcome as it is occurs in the evolving forest, in comparison with the objectives as stated in the plan, is corrected by changing the objectives, the plan, the implementation, or all three.

Having established this linear continuum, it is helpful to have a set of criteria by which to analyze actions, either ones in place or those proposed. A useful checklist for review was described by Clawson (1975, 1987), who will be familiar to many as a speaker at the 1980 Canadian Institute of Forestry annual meeting in Jasper. He suggested the following five criteria for evaluation:

1) Physical and biological feasibility and consequences: This addresses such questions as is the wood there in the volume, quality, cost, and the year needed? Is it renewable and sustainable for these same factors? Is management to meet these needs compatible with wildlife and environmental concerns? These concerns are similar to those expressed by Montaigne (1533–1592), who said, "Let us a little permit Nature to take her own way; she better understands her own affairs than we." Similar sentiments were expressed by Sir Francis Bacon (1560–1626): "We cannot command Nature except by obeying her."

2) Economic efficiency: In essence, will it pay? Will the benefits outweigh the total costs? It is also important to recognize that "profit" is not a four-letter word but represents the primary economic force that makes management activities possible.

3) Economic welfare or equity: This addresses the question of who benefits, and who pays. Is society a net beneficiary?

4) Social and cultural acceptability: Our recent visitor from California, Harold Walt, confirmed that we can expect this to be an increasingly major compelling force. This means involving in our management planning those affected by management decisions. The advantage to addressing this criterion in advance is that if concerns can be identified early enough, we can either adapt our approaches to them and/or try to change the points of view of those particularly affected.

5) Administrative practicality: This represents the "belling the cat" syndrome—will it work? Can the infrastructure of funds and human resources be provided, or can effective administrative mechanisms be worked out?

These considerations provide us with a two-dimensional matrix on which we can add the questions arising from these discussions to provide a three dimensional model for analysis.

GOALS OR OBJECTIVES

Of all the questions, that of goals or objectives is the most fundamental. If we do not know where we are going, there is not much point of discussing how to get there. We must first determine what we wish to achieve, and temper that by recognition of what is possible to achieve. It is then easier to design the approach to fit the location-specific situation and needs.

Our earlier objectives in Alberta have served us well. Although these were not explicitly stated, they were commonly understood: a) protecting the forests to keep the wood available and to provide us with management options, and b) developing products and markets for mixedwood forests in the meantime. Recent developments and announcements have substantiated the validity of these earlier decisions.

The success of our fire control activities presents an interesting perspective to these discussions, as outlined by previous speakers. In 1909 the fire cycle in these northern mixedwood forests was 38 years (Murphy 1985). This term suggests that, on average, any one point in that forest could be burned over once every 38 years. In actual fact, there was substantial variation, but the index is a useful figure. By 1929, after the early efforts of the Dominion Forestry Branch, the fire cycle had increased to 48 years. By 1969 it had become 90 years, based on averages. Looking at the 1950–69 interval specifically, the fire cycle had increased to 384 years. This strongly suggests that we must now develop

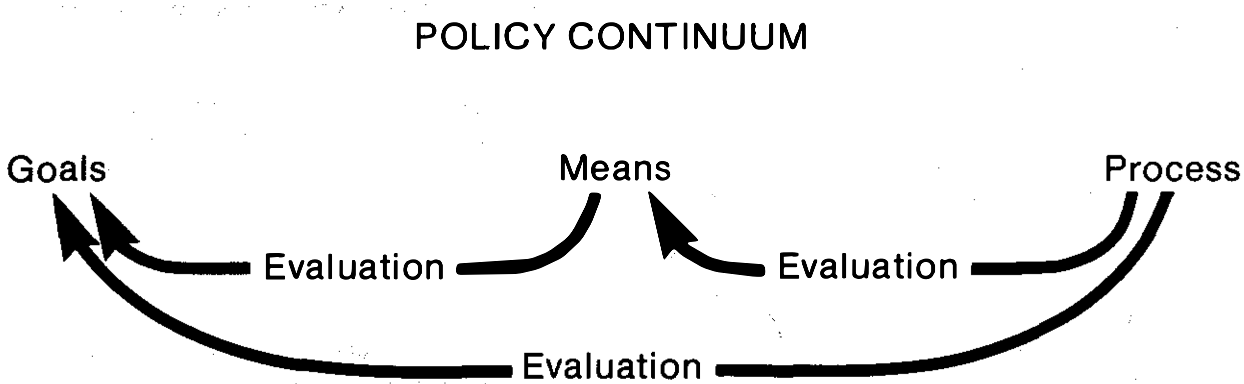

Figure 1. The forest policy continuum.

forest harvesting treatments in those areas in order to maintain ecological stability and diversity of age classes.

In the present discussion of establishing goals for mixedwood forest management, we seem to be looking at two major situations: those where harvesting rights on forested lands have already been committed, and those where harvesting rights are not yet allocated.

On areas already committed, I suggest that the objective will already have been set if not specifically stated. With specific annual allowable cut volumes of softwood and hardwood stipulated in the agreements, the question becomes essentially one of how to continue to supply these volumes and species to the mills at the times required. This timber supply will have to be sustained as part of the contractual commitment, at least until the industry needs change.

Although these agreements were made in good faith based on best estimates, some disquieting questions now seem to be emerging about how realistic these commitments are. Will the wood of the species, kind, quality, and cost actually be available at the times and places needed? These questions suggest opportunities for conducting strategic analyses on the basis of forest management agreement (FMA) or management unit areas to help us to identify and specify possible types and times of shortfalls. If these exist and can be recognized now, the results would better enable us to develop appropriate policy strategies for addressing them.

An example from New Brunswick illustrates such problems (Baskerville 1983). The bar chart (Fig. 2) illustrates the uneven age-class distribution in New Brunswick in the late 1970s. It will be quickly recognized that the wood available for current harvest is already out there in place, and that there is a gap before the new forest becomes large enough to meet future needs.

The resulting timber supply situation is depicted in Figure 3, showing the availability of timber projected over time. The shortfall from 20–40 years is clearly evident.

The management options for the old growth forest and established young growth fell into two general categories: protection from fire and insects to extend availability of the old growth, and acceleration of growth through stand treatments. The second general approach was a focus on quicker forest renewal with improved stock, and bringing nonsatisfactorily restocked areas into production. The simplified result is illustrated in this current management scenario (Fig. 4) in which the gap is expected to be largely filled by these approaches.

Similar analyses here on a management unit-specific basis could help to answer some of the questions posed during this session, such as whether we should be managing for hardwoods or softwoods, in what proportions, and how. This analysis addresses the criterion of physical and biological feasibility, and can provide insights to addressing specific program needs. If, in our case, softwoods are projected to be in short supply, treatments will have to be developed to favor them; conversely, hardwood treatments will be needed if hardwoods are in short supply.

Where commitments have been made on a volume basis, such as in quota allocations, and where softwoods and hardwoods are growing in the same stand, we need also to look at the physical feasibility of removing only one species without destroying the other. If this is not possible, thus leading to the unavailability of one of the two species, this should also be considered for strategic calculations to be realistic. Until we can demonstrate successful techniques for harvesting only one of two species, volume allocations must be made only on the basis of one of the two species in the stand unless both can be harvested simultaneously.

Where commitments have not yet been made, more options are open, and we have time to explore further the mixedwood management scenarios to optimize production presented here.

In my view it appears logical to manage for a mixedwood characteristic to provide flexibility for forest industry—especially in light of the flux in global markets—and to maintain ecological diversity. When we examine the aspects of quality and value, however, there is still compelling evidence that our softwoods deserve special attention at least to maintain their present proportions. The evidence includes the demonstrated competitiveness of our SPF (spruce, pine, and fir) in distant markets despite high delivery costs, and the value of the Scandinavian conifers with their demonstrated value-added capability.

Once objectives have been established, specific means such as programs, projects, practices, or approaches can be developed, selected, and tailored to meet needs on a location-specific basis.

TENURES

In our methods of allocating timber harvesting rights we have evolved from one of government-industry competition to one of cooperation through forest management agreements and quotas. These have been especially

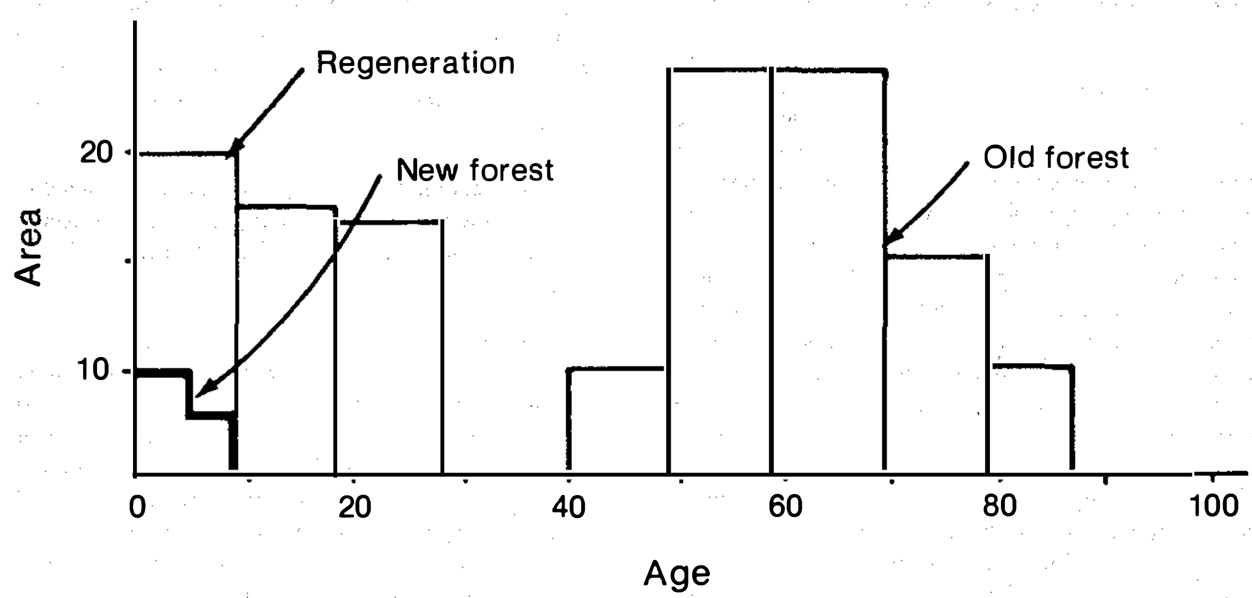

Figure 2. New Brunswick age-class distribution in the late 1970s (Baskerville 1983).

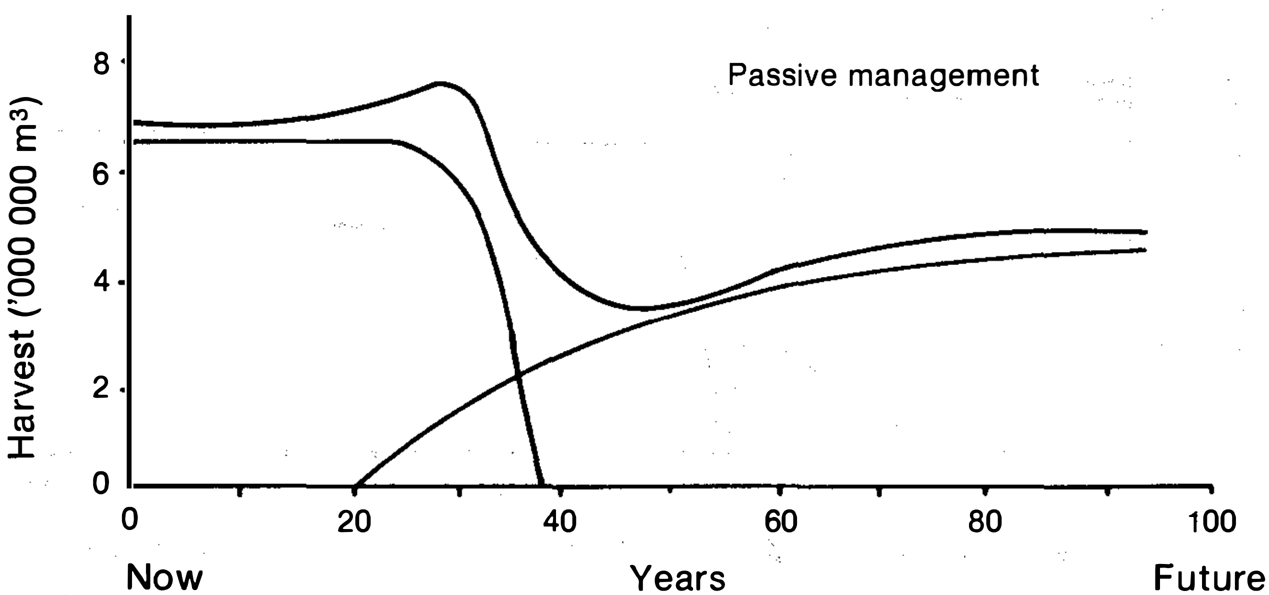

Figure 3. New Brunswick timber supply projection based on 1970s management levels (Baskerville 1983).

successful for single-product harvesting situations. Now, however, in the more complex mixedwood case with multiproduct and multiuser situations, we should postulate a different approach that would 1) foster and encourage fuller interindustry cooperation in addition to industry-government cooperation, and 2) provide an inducement for integrated products and intensified forest management.

For example, could we consider revising some of our committed forest management units from quota to forest management agreements with an area-based form of tenure? Management responsibility should be assigned to a single legally responsible entity, as in the case of present FMAs; however, the entity may be in the form of a consortium of the industries involved, a management corporation of them, or a designated lead company as primary licensee that would be responsible first for providing wood to the other operators on a sublicense basis. A form of this latter situation is being employed on some units in New Brunswick. Such an approach should go a long way toward addressing the criteria of economic efficiency, equity, and administrative practicality. It should provide for coordinated planning and management, coordinated harvest scheduling and wood allocation, renewal responsibility, and an incentive to increase forest productivity.

Our forest industry has matured and demonstrated responsibility, and there are enough examples of interindustry cooperation to suggest it could work. Consideration could be given to setting up an objective mediation tribunal to assist with some of the adjustments and to handle appeals. Such a tribunal might comprise a representative each from government and industry, along with an arms-length member from the university or consulting community. To make such an arrangement work would require a spirit that I believe exists here, which leads me to my next two points.

The resulting timber supply situation is depicted in Figure 3, showing the availability of timber projected over time. The shortfall from 20–40 years is clearly evident.

The management options for the old growth forest and established young growth fell into two general categories: protection from fire and insects to extend availability of the old growth, and acceleration of growth through stand treatments. The second general approach was a focus on quicker forest renewal with improved stock, and bringing nonsatisfactorily restocked areas into production. The simplified result is illustrated in this current management scenario (Fig. 4) in which the gap is expected to be largely filled by these approaches.

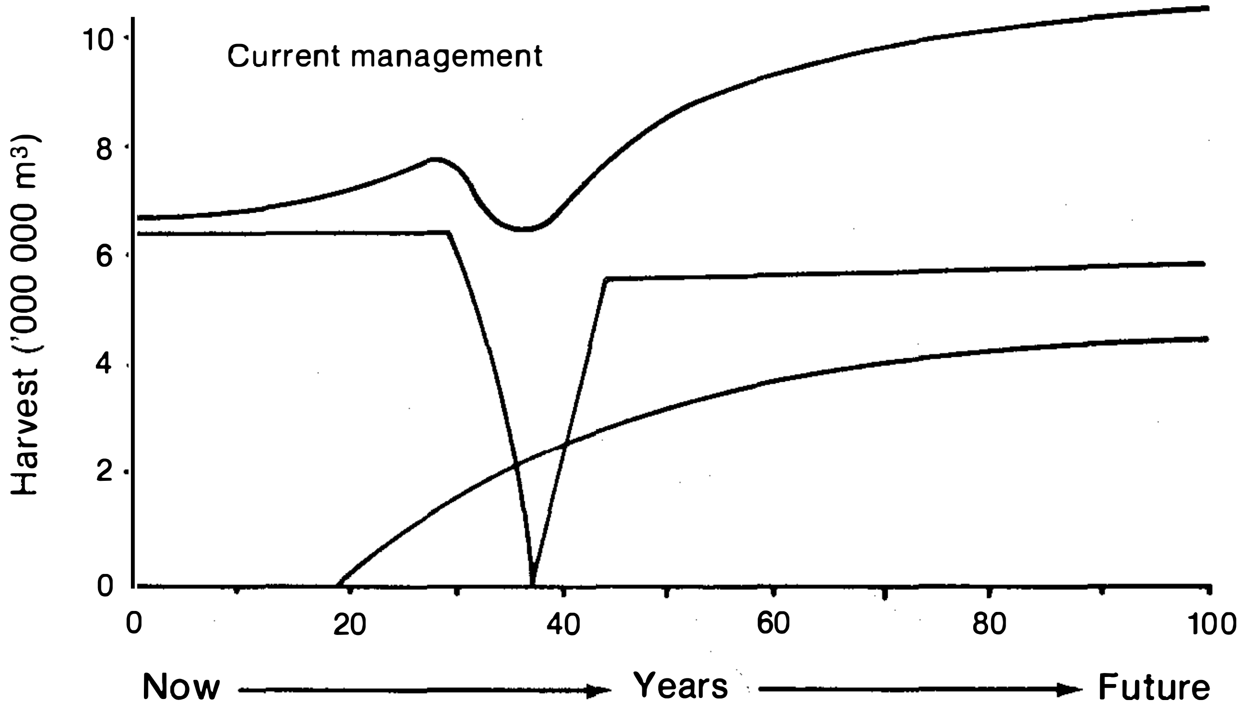

Figure 4. Projected New Brunswick timber supply based on proposed, intensified management programs (Baskerville 1983).

PROFESSIONAL JUDGMENT

Given the complexity of forest ecosystems, environmental situations, and economics, we cannot and should not try to legislate everything in detail from the act through to groundrules. Reg Loomis had a motto on his office wall during the 1960s that said something along these lines: "Rules and regulations are for the guidance of the wise—and for strict adherence by fools." Referring to a higher authority, although in a different context,these words convey a similar message: "Not of the letter but of the spirit; for the letter killeth but the spirit giveth life." (2 Cor. 3:6)

Leaving room for a combination of professional judgment and accountability is strongly urged. Like Jonathan Livingston Seagull, we should aspire to increasingly higher planes of experience. Leaving room for professional judgment would help to avoid situations in which policies sometimes seem to get in the way of doing what should be done. A spirit of this sort has developed, and I hope it can be sustained.

TRAINED INCAPACITIES

These are a reflection of the culture in which we live in, whose complexities seem to encourage us to generalize, to build on preconceptions, and to constrain thinking. S. I. Hayakawa expressed it well when he said: "If you can see in any given situation only what everyone else can see, you can be said to be so much a representative of your culture that you are a victim of it." John Lubbock said more succinctly: "What we see depends mainly on what we look for." As John Drew pointed out, Waterman (1982), in his *In Search of Excellence*, noted that people could be categorized as "warners," those who advise of problems, and "innovators," those who treat them as challenges and improvise solutions. Fortunately, we have a reputation in this region as mavericks, full of imaginative and innovative solutions, an essential ingredient to solving our problems.

TREE IMPROVEMENT

Different points of view were expressed about clonal quality and tree improvement in hardwood management. After struggling to establish spruce regeneration, we frequently rejoice in the plethora of hardwood regeneration that results after harvesting. In stands in which hardwood management will be a focus, we must also be alert to the importance of growing quality trees, which may frequently require clonal conversion to superior strains. The work of the International Poplar Commission in Europe is worthy of note in this connection. Its major mandate has been to search for, test, and register superior clones of poplar for improved quality production. We would be wise to emulate that example as part of our strategic policy.

RESEARCH AND DEVELOPMENT

Sustained and increased programs in research and development are essential to keep hitting at the identified questions that have emerged at this symposium. These questions cover a full range from forest-based concerns to harvesting, manufacturing, product development, and sales.

SOCIAL AND CULTURAL ACCEPTABILITY

We are being watched in our activities by an increasingly aware public, as evidenced in letters to the editor and representations to government. It is important that we perform and demonstrate sustained and sustainable forestry by ensuring regeneration, tending the stands, and fostering the next crop. The public will not stand to be deceived—not our Alberta public, not our U.S. competitors who are sensitive to possible indirect subsidies and underfunded management, and morally not by our global counterparts.

PRIVATE LAND FORESTRY

Aspen on some private lands is being harvested now, providing a positive economic opportunity to the landowners. There are many questions related to harvesting in this private sector, including landowner perceptions, needs, inhibiting factors, and attitudes. In his graduate study program, Don James will help to provide some answers to these questions through his analysis of questionnaire responses. In the meantime, however, two areas of concern have been identified. Some landowners are using sales of wood as a means to clear land for agricultural production, and not as a first step in renewing and sustaining a forest crop. This may not necessarily be an inappropriate use of land, but is an eventuality that should be considered in estimates of sustainable wood supply from this sector. Secondly, some landowners, after viewing the results of harvesting, apparently feel taken advantage of by logging contractors. This may be just a perceptual problem but should be investigated. It will be important to cultivate cooperation from private landowners to enlist them as continuing rather than just marginal suppliers, and to develop appropriate programs with them to assist in their forest land management.

CONCLUSION

Returning to the B.C. Provincial Museum, I suggest that our mixedwood forest is also a prize, like the wooly mammoth was a prize—a large and impressive resource. But the forest is amenable to sustained management and, if we do it right, it will not be necessary to replicate a mixedwood forest in our own Alberta provincial museum—the forest will be right here to enjoy firsthand.

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SYMPOSIUM SUMMARY

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I do not intend to summarize each presentation, but I will try to present, usually without reference to the speakers concerned, an overall picture of the conference. Over the 2 days we have heard repeated speakers indicate the challenges, opportunities, problems, and situations (COPS) we face in the future to use our mixedwood forest. These COPS range over the whole gamut of marketing, innovation, and processing of products to harvesting, growing, and regeneration of mixedwood forests. They range from actual physical-biological COPS to policy-tenure COPS. I would like to mention some of the underlying themes that I heard.

The mixedwood forests are highly productive but have been, by and large, avoided until recent technology and marketing changes have now turned "the weed" aspen into a "Cinderella tree". Now that both the coniferous and deciduous species are worth money, we have a tiger by the tail. Regeneration concerns of the past regarding conifers and how to keep the boreal mixedwood as mixedwood instead of boreal hardwood are now enhanced and even of more concern. Old solutions, once thought clear at least to some, to eradicate the aspen and grow conifers are suddenly out of focus. Now that aspen has value, what priority, if any, do we give conifers? Repeated speakers agreed that we need to establish realistic values for each. Many foresters clearly see for our existing stands a future in which we would need the existing conifer understories. Others (at least one anyway) say, "Forget it; grow one or the other, and don't dink with mixes." Interesting to me, however, is that both groups advocate partial harvesting as integral parts of their systems. Many speakers questioned whether our values can justify this type of harvesting, and many put it another way: "Can we ask our harvesters to absorb these higher costs or lower production rates?" In other words, who pays for the increased cost? No one dared to say that he or she who wants the wood for commercial purposes will, in the end, pay.

One moderator reminded us that we must manage what we have, not what we wish we had. When I remind myself of that, I don't believe the presentations by Lorne Brace and Bob Day are quite so opposite. Brace's presentation talks about what we have, and Day's talks about what we can have if we eliminate what we have.

It is clear to me from the speakers' thoughts that mixedwood management will require: 1) a more intense management effort; 2) in most cases a revised set of policy and harvest regulations; 3) careful coordination between overlapping tenures; 4) a better understanding of site; 5) more continuous and probably better access; and 6) more concern for multiple use aspects.

On this latter issue, many speakers mentioned wildlife or other concerns. One pointed out, however, that mixedwood management made things tougher. You cannot slough off or suggest use of those hardwood areas as areas that will not be harvested. Area-wise, a higher percentage of any one area is clear-cut when harvesting occurs. This can create increased concerns regarding watershed management, wildlife cover, recreation, and aesthetics. Several speakers dealing with such issues as tenures and policies suggested that old conifer systems are getting in the way, but several also indicated that there are workable alternatives toward which we can, will, and must evolve.

Many comments struck me, and I would like to paraphrase a few without other comment.

1) To grow spruce we have a grass-bunny-aspen problem, or, as others put it, a grass-brush-bunny-aspen problem.

2) We cannot manage without access and the saw.

3) We cannot manage without clear objectives for management.

4) Total use intensifies multiple-use concern

5) We must manage what we have, not what we wish we had.

6) Who pays for more-expensive logging?

7) Can we afford to protect all the spruce understory?

Several speakers indicated that it is a new world and we must be progressive in our approach. One speaker put it best: we all must learn new tricks.

1) We have to stay innovative in our approach to solutions.

2) We must change from a volume to a value approach.

3) We must listen to our clients.

4) We must take care not to continue the old ways of doing things in this new world of increased utilization, new products, new markets, and new grading standards.

To Ed Packee and all the other Alaskans, all I can say is, "Be patient." Your story sounds like what I heard in Alberta when I arrived here 17 years ago. In the future, I assure you, there will be technological changes that will make your forest economic to utilize. Our solutions now will not magically make your forest merchantable. What you need is a new technology-marketing innovation that will make your aspen your Cinderella tree.

I am left with a couple of questions for which I did not hear answers.

1) Herbicides: When aspen was worth nothing, we had difficulty justifying to the public and politicians the use of herbicides to get increased conifer yields. Now that aspen is worth something, our justification is even more difficult, because all we get now is the difference in value of the increased conifer over the value of the lost aspen. Good luck! I suspect that we are banging our head against an awfully thick wall.

2) Clear-cut loggers worldwide fail as partial-cut loggers, at least initially. It takes time and patience to develop partial-cut loggers with an ethic for the residual forest. It can be done, however, as it has been done elsewhere in the world. On the other hand, in those places wood has been more valuable per unit than here. Have our values increased enough so we can afford to move into this type of logging? If so, I believe many possible alternatives have been offered at this conference. If not, we still have large problems, or should I say opportunities and challenges?

I personally would like to thank all the speakers who shared their ideas with us over the last 2 days and the organizers for an excellent program. I know I have learned a lot, and I suspect most of you have as well.

CLOSING REMARKS

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During my introductory comments yesterday morning I expressed the hope that this symposium would live up to your expectations. Today I hope that you agree with me that it did so rather emphatically!

For the Canadian Forestry Service (CFS), there are immediate benefits in terms of technology transfer opportunities and the updating of the information base about mixedwood management and utilization. I expect that we will make full use of this information as we proceed with the development of a research strategy for the management of white spruce and aspen on mixedwood sites. We want to be sure that the mix of research, task forcing, and technology transfer reflects the needs and priorities of management agencies.

I attribute the success of this symposium to three things:

1) New interest in mixedwood management and utilization. The mixedwood belt is expected to provide much of the wood fiber for a number of production plants in Alberta and elsewhere within this vegetation type. Symposium attendance in excess of 250 is ample proof that the topic is extremely timely.

2) The moderators and speakers were knowledgeable and effective in delivering their message. The papers were of a uniformly high quality and well-focused on the main theme.

3) The organizing committee. A symposium of this scope and size requires much planning and behind-the-scenes organizing. I would like to recognize Steve Price for his willingness to take on the job of symposium coordinator and congratulate him for a tremendous accomplishment. Steve has built up quite a network of contacts, and the quality of the moderators and speakers reflected this! Bob Newstead also deserves special recognition for his contribution. Other CFS staff members, including Avery Ascher, Ron Gorman, Claire Abma, Diane Szlabey, and John Mrklas, assisted in various capacities.

We will be producing the symposium proceedings, and I am challenging our Information Project staff to ensure that the publication is available as soon as possible, i.e., within 3 to 4 months.

Ladies and gentlemen, this concludes our second forestry symposium. We expect to continue with this series of forestry symposia and would appreciate your feedback about timely issues and topics for future sessions.

Thanks for coming!

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