TABLE 8. Estimated production in 1990 and 1995 by Finland's forest industry.
(Source: Forest 2000 Programme)

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<tr>
<td></td>
<td>1000</td>
<td></td>
<td></td>
<td>%/yr</td>
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<tr>
<td>Conif. sawnwood</td>
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<td>Plywood</td>
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<tr>
<td>Particle and fibreboard</td>
<td>m³ 724</td>
<td>730</td>
<td>730</td>
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<tr>
<td>Total paper and board</td>
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<td>11300</td>
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<tr>
<td>• Newsprint</td>
<td>t 1715</td>
<td>1500</td>
<td>1500</td>
<td>-1,3</td>
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<td>t 3115</td>
<td>4600</td>
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<td>• Other paper and board</td>
<td>t 2513</td>
<td>2900</td>
<td>3400</td>
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<tr>
<td>Total wood pulp</td>
<td>t 7913</td>
<td>9400</td>
<td>11200</td>
<td>3,5</td>
</tr>
<tr>
<td>• Mechanical</td>
<td>t 2865</td>
<td>3500</td>
<td>4300</td>
<td>4,1</td>
</tr>
<tr>
<td>• Chemical</td>
<td>t 5048</td>
<td>5900</td>
<td>6900</td>
<td>3,2</td>
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SWEDISH MIXEDWOOD MANAGEMENT

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On the whole, the biological conditions for forestry in Sweden and British Columbia are very similar. Although the species are not the same we have, in both countries, the dominating conifers pine and spruce, and also birch and aspen. Apart from this there are many differences.

British Columbia has twice as much forest as Sweden and it is almost all state owned. In Sweden 50% of the forests are owned by farmers, about 25% by companies and just under 25% by the state.

Another very important difference is that in Sweden sustained-yield forestry has been practiced for about 150 years. This forestry has been regulated by laws which all forest owners, including the state, must follow. Every forest owner is, for example, required to have an up-to-date management plan for his forest holdings. This plan must include statements of the need for silvicultural measures, suitable areas for felling, etc.

Sweden is close to the European market where there is a great demand for imported wood products. We have an extensive network of roads and railways and in the past also used many rivers for floating timber down to the coasts where most of our forest industries are still located.

Because of these conditions our industries have gradually learnt to utilize and sell products from all of these tree species.

Aspen is used to manufacture: paper pulp, fibreboard, matches and packing. We use birch for: paper pulp, plywood, veneer, fibreboard, particle board, furniture, folding rules, joinery, packing, pallets, toothpicks etc.

We have, therefore, no technical difficulties in processing birch and aspen, and although we fell about 11 million cubic metres of deciduous trees per year, we also import about half a million cubic metres per year.

The trend for the near future is rather clear. The country’s pulp industry needs an increasing amount of hardwood raw materials. Sawmills, the board industry, the furniture industry and the joineries can all use more hardwood.

All seems well, but what kind of forests and silviculture do we have? On our growing stock of 23 million hectares (which includes bare ground and all age classes), we have an average of about 100 cubic metres per hectare. This volume consists of 15% deciduous and 85% conifers.

The growth is distributed somewhat differently, that is, 19% deciduous and 81% conifers. Deciduous trees grow faster than conifers.

This situation would appear satisfactory, provided the deciduous trees grew in pure stands. This is not the case. Only 5% of our forests could be described as pure deciduous forest. This obviously means that a very large amount of the hardwood stock grows in mixed forests of pine or spruce, or both pine and spruce. In fact, as much as 70% of the hardwood volume can be found in mixedwood forests. This is a problem. Mixed coniferous forests also occur, of course, but as a rule these can be found on sites of average quality class where pine and spruce reach the same height up to the time of final felling. In these cases pine and spruce can be treated equally for the one, two or three thinnings which the stand will undergo during rotation. Therefore, this type of mixedwood forest does not present a management problem.

What then are the problems with deciduous trees? Aspen and above all birch are regarded as pioneer trees both in Sweden and in British Columbia. Every year 1% of our forest area in Sweden becomes bare forest land because of final felling. The result is that aspen and birch spread and grow at an enormous rate, especially after forest fires or controlled burning.

When these naturally regenerated deciduous trees appear on ground which, because of its site quality class, is best suited for pine and/or spruce, we regard them as weeds of the forest. Weeds which we could have controlled or eliminated earlier if we had used herbicides. We no longer have that alternative.
So what steps do we take? Because our principle objective is to produce good coniferous forests, it is therefore important to carry out site preparation, adequate for the site in question, very soon after final felling of the mature forest. This means that all clear-felled areas must be cleaned. Then soil scarification must be carried out in final preparation for planting.

If these preparations are carried out quickly and good coniferous seedlings are planted, there is a good chance that they will grow well.

In this way competition from the natural regeneration of deciduous trees can be reduced. One should be aware that on bare forest land surrounded by forest containing seed spreading deciduous trees, it is not advisable to expose more mineral soil than is necessary for good forest planting. A careful analysis can sometimes show that it is not necessary to prepare the entire area. In Sweden approximately 90% of forest area needs preparation before planting.

For areas where one can expect a high level of natural regeneration of deciduous trees, site preparation should absolutely not be carried out using a harrow or other continuously operating machine. One should use an intermittently operating scarifier which will make a patch for each plant. In Sweden the number of patches varies with the site quality class and is usually between 2,000 and 3,000 per hectare.

I would like to point out one exception to the rule of complete cleaning after clear-felling. Some areas of good ground, suitable for spruce production are low-lying in relation to the surrounding area. These areas are called frost holes as they can experience heavy ground frost in the early summer which can damage and sometimes kill small spruce plants. For these areas it is advisable to carry out a limited cleaning operation and leave about one thousand deciduous trees per hectare as a frost shield. When the spruce have grown to a safe height of about 3 or 4 metres, the frost shield can be removed. The spruce continue to grow and the deciduous trees are eliminated.

Let us now return to the ordinary thicket stage.

One or two years after planting an examination of plant survival is carried out. A certain level of mortality must be accepted. However, if the level is too high, a supplementary planting must be done as soon as possible using the same species as originally planted. At this point, or at the very latest when the planted trees are 2 or 3 metres high, the Swedish Forestry Act requires all forest owners to carry out the first precommercial thinning if the young forest is growing too densely or, for example, if the proportion of deciduous trees in a coniferous forest is too great.

In precommercial thinning:

- the types of trees most suited to the ground are to receive priority - the trees of the best quality are to be saved - a suitable number of trees (in accordance with site quality class) are to be left and
- the distribution of trees over the area is to be relatively even.

In this question there is no conflict of interest between the forest owners and the law. There is a common goal. It is a matter of getting good quality trees of the right species as quickly as possible on the area in question.

During this thinning one also has the opportunity to leave a suitable number of trees for the remaining one, two or three commercial thinnings in the program before final felling. These thinnings provide further opportunities for controlling the mix of species and final felling of all deciduous trees can be done at the time of the final thinning. In this way a stand of pure conifers can be achieved before final felling.

Precommercial thinning is usually carried out with brush saws. However, since the ban on herbicides, intensive efforts have been made to try to develop a mechanized technique. We now use rotating blades mounted to the crane rotor of a small forestry tractor. My company, STORA, has taken part in this work and the results have been so successful that ten units are now being procured.

Compared to manual operation with brush saws this new technique costs less, and the damage to remaining plants is quite acceptable. A requirement is that the work be carried out before the conifers become too big. They should be less than 1.5 metres if the ground clearance for the tractor is 8 to 9 decimetres.

An additional advantage with the mechanized technique is that it can also be used in 60 to 70 centimetres of snow. It can, therefore, be used through most of the year.

I do not know about the birch’s stump sprouting ability nor the quantity of root suckers produced by aspen in British Columbia. However, our experience in Scandinavia has shown that the best thinning results for birch have been achieved during the few weeks of early summer directly after the new leaves have fully developed. At this stage the trees have spent their energy on producing the new crop of leaves and their ability to sprout is greatly reduced.
If deciduous trees are cleared away at the right time and with care, and by that I mean that stumps should be as short as possible and the trees completely cut away from them, then one thinning should be enough in most cases.

On very fertile ground it will sometimes be necessary to repeat the thinning operation. Especially if the first thinning was carried out too early or the stumps were not cut short enough.

I have now covered the establishment of new forest and silviculture in your forests aimed at reducing the influence of deciduous trees in coniferous forests.

What action do we take when managing forests that are mature or over mature with a mix of birch and aspen? How do we carry our reproduction cutting aimed at having the lowest possible level of deciduous trees in the next generation of trees?

I suspect that this might be a big problem in British Columbia and that it is connected to the lack of hardwood processing industries.

However, as I am not an expert on industry I will return to forestry. As I mentioned earlier, in Sweden we have been practicing sustained-yield forestry for a very long time, where the deciduous trees are gradually eliminated during thinning. Mixedwood during final cutting is, therefore, not a great problem. But when it does occur, we often work according to the following model.

In stands with a birch mix, thinning is done 10 years before final felling to remove all birch trees. In the thick forest no sprouting occurs from the birch stumps and a well planned system of strip roads reduces any negative effects on the conifers to a minimum.

Stands with a mix of aspen are treated differently. To avoid root suckers the aspen trees must be killed before final felling of the stand. To get the best results, nothing, if allowed, or girdling should be carried out at least 3 years beforehand. There are different methods of girdling. I believe the cheapest and best results can be had by using a light chain saw and cutting through the bark around the tree.

The term silviculture covers what I have described so far.

In Sweden silviculture means: planning, surveying, mapping, clearing bare land, ground preparation, planting, removing deciduous trees from mixed stands, precommercial thinning, draining, fertilizing, nature conservation.

Silviculture costs money.

STORA, the company I represent, owns about 1.5 million hectares of forest. Rotation for these forests is on average about 100 years. This means that every year we clear fell about 15,000 hectares and this area is then treated as I have described.

The total cost for this silviculture is about 50 million Canadian dollars per year. That is about 33 dollars per hectare of forest land or 13 dollars per felled cubic metre.

And now a short summary of how the problem of mixedwood can be reduced in the future.

Prepare the site, plant conifers, clear deciduous thickets, reduce the deciduous mix when thinning, cut down birch trees in mature forests 10 years before final felling and kill aspen trees in these forests for at least 3 years before final felling.
NORTHERN MIXEDWOOD RESEARCH - IMPLICATIONS OF GENETIC IMPROVEMENT

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ABSTRACT

The history, potential and state-of-art of the breeding programmes in aspens, poplars and birches, with reference to northern mixedwoods, is briefly outlined. The potential for genetic improvement is considerable, but a well planned re-activation of these programmes is needed if improved stock is to be produced within the next 10-15 years. The management of mixed species plantations could pose additional problems. Hybrid poplar clones could be successfully grown on alluvial terraces in the major river valleys in the Boreal Forest Region, but we have neither tested clonal varieties nor plantation management practices for such plantings.

Criteria for the identification of superior and inferior genotypes of aspen are not well established. The replacement of inferior aspen stands with a different species seems more feasible.

INTRODUCTION

Canada has recognized the need for better utilization of trees and increased forest yields. Recent actions by forest industries and governments emphasize this recognition. Increased efforts in genetic improvement must be an important part of these undertakings.

The genetic improvement of trees is a relatively long term proposition, and it's results are only seen in a new generation of forest. However, genetic improvement work with forest trees in Canada started more than fifty years ago. Tree breeding programmes are well established in most provinces, using species which have been considered commercially important. In many cases, new generations of forests are already established with genetically improved stock. Nevertheless, in order to meet the needs of intensified forest management, and with additional tree species gaining commercial importance, some re-orientation of genetic improvement programmes will be needed.

Aspen, birch, spruces and pines appear to be the important species of northern mixedwoods. Genetic improvement programmes in Canada are well established and active with spruces and pines, which have been considered commercially important species.

However, these programmes are incomplete and inactive with aspen and birch, which were considered weed species until recent times. This situation is exemplified by the fact that there was not a single report on genetic improvement work in aspens presented either to the annual meetings of the Poplar Council of Canada in 1985 (Timmins, Ontario) and 1988 (Edmonton, Alberta) which focused on aspen, or in the series of articles published in Forestry Chronicle (1989) under the common title "Managing for Aspen - A Shared Responsibility."

BREEDING PROGRAMMES IN HARDWOODS

Breeding programmes in poplars (including aspens) and birches have been more active in Europe than in North America. Poplar culture in Europe and Asia goes back to biblical times, and so does the selection, propagation and use of several cultivars, such as Lombardy poplar. The introduction of Populus deltoides some 200 years ago was undoubtedly the most important single event in the modern story of poplars in Europe (FAO 1979). Soon afterwards, natural hybrids between this American species and the European P. nigra started to appear, giving rise to P. x canadensis (P. x euramerica) cultivars, the culture of which spread to all of Europe and other continents.
From the 1930's, breeding programmes with poplars intensified and resulted in more superior clonal selections. Outstanding examples of these are in Italy (Prevosto 1969) and Belgium (Mühle Larsen 1970). The new clonal selections of hybrid poplars showed significant improvement over the spontaneous *P. x canadensis*. These new generations of clones, resulting from well planned genetic improvement work, outperformed the early selections significantly, sometimes by 2-3 times. These new clones were also better in site adaptation, pest resistance and wood qualities (IUFRO 1979).

Poplar breeding in North America also started in the 1930's; in the U.S.A. (Schreiner 1970) at the North Eastern Forest Experiment Station, and in Canada (Heimbürger 1968) at the Petawawa National Forestry Institute. Breeding in the U.S.A. included a larger variety of poplar species (such as different species of *Tacamahaca* section in crosses with cottonwood-type poplars) than in the 1930's to 1950's in Europe, and resulted in very good clonal selections of hybrids. However, the poplar culture never spread in larger areas, because of the relative abundance of timber and different needs of the forest industry in North America at the time.

Aspen breeding started at about the same time as poplar breeding. In Europe, the Scandinavian countries and Germany, among others, had good results especially with *Populus tremula* x *P. tremuloides* hybrids (Johnsson 1956). These were superior to selections from native *P. tremula*. In North America, work focused on *P. tremuloides* x *P. tremula* and *P. alba* x *grandidentata* hybridization, and the development of triploid aspen (Heimbürger 1968, Eisnähr and Winton 1977). Despite the good results obtained in these breeding programmes, aspen plantations have not spread to large areas either in Europe or in North America. The limitations included problems associated with vegetative propagation of aspen varieties and pathogens of aspen, especially the canker diseases. Furthermore, in North America, less demand for aspen wood has contributed to limited plantation management of aspens.

There is a long tradition of birch breeding in Europe. For example, in Finland, seed orchards currently produce all of the selected European white birch (*Betula pendula*) seed required for planting (Fern et al. 1985). Progeny tests in Finland indicate a 30% improvement in volume growth from present seed orchard material compared to non-bred provenances (Lepisto 1981). Properly managed birch plantations established with genetically improved stock grow excellent trees and give a completely different impression from the one we get when looking at mostly degraded stands of paper birch in Canada.

Genetic studies in birches began in North America in the 1940's (Clausen and Garrett 1969), but genetic improvement programmes have never really advanced. More interest has been paid to yellow birch, a high quality timber species of the northeastern hardwood zone, than to paper birch. It is likely that selection and breeding in paper birch would result in gains similar to the ones experienced in Finland. Also, properly managed plantations with improved stock would bring increased yields and high quality timber.

**POTENTIAL FOR GENETIC GAIN IN MIXEDWOOD STANDS**

The potential for genetic gain in mixedwood stand species is considerable. As discussed, in Finland, stock from seed orchards grown in properly managed plantations produces a 30% gain in volume growth. Poplar clones resulting from good breeding programmes are several times better in growth and form than the natural trees. Considerable improvement can be expected from spruce and pine breeding programmes as well. The gains expected in these species from seed orchards range from 4% to 20% (OMNR 1987). The question is whether such potential gains can be realized with the present limitations in breeding programmes and management practices.

Breeding programmes with white spruce, sitka spruce, black spruce, jack pine and lodgepole pine have advanced in Canada and in most localities these programmes can supply selected seed from either seed production stands or seed orchards. This seed is a guarantee of successful plantation management and improved growth, although at a more moderate level of gain (4% to 8%) than discussed above. Breeding programmes with aspen and birch are not active at the present time in Canada and can not deliver genetically improved stock in the immediate future. Newly activated programmes could build on the previously accumulated knowledge and genetic resource, but would need considerable support and at least 10-15 years to deliver.

The second limitation in using the potential gains offered by genetic improvement lies in mixedwood management practices. There is very little experience in planting and managing plantations of mixed species. Considerable experimentation and time would be required to gain such experience. Also, specially selected stock which tolerates, or even favours growth in mixed stands may be needed. We have not tackled this question as yet. Naturally, managing blocks of pure, single species plantings would be an entirely different proposition. There is considerable experience with management of pure plantations,
especially of coniferous species, in Canada. There is also some experience with managing hybrid poplar plantations. There is much less experience with aspen and birch plantation management in Canada. However, this problem is being undertaken in conjunction with management of aspen stands. Some earlier references (Heaney et al. 1980, Hambly 1985), several reports presented at the Poplar Council of Canada annual meeting in Edmonton, Alberta, 1988, the Joint Technical Session of the Canadian Institute of Forestry's working groups in Prince Albert, Saskatchewan September, 1988 (Forestry Chronicle 1989), and several presentations at this Symposium witness this situation. Also, foreign experience could be used as a first resource when needed.

**POTENTIAL FOR THE USE OF HYBRID POPLARS IN THE MAJOR RIVER VALLEYS OF THE BOREAL FOREST REGION**

In the context of this discussion we consider hybrid poplars the clonal varieties of *Aigeiros* (cottonwoods) and *Tacamahaca* (balsam poplars) sections and their interspecific hybrids. Such hybrid poplars have been used extensively in the poplar cultures of Europe, and also in the U.S.A. and Canada (especially in Eastern Ontario - OMNR 1983). Clonal selections are available for a variety of soils (most of these will grow very well on alluvial soils), but only in temperate climates. Trials which I established in the 1970's with a variety of hybrid poplar clones in Boreal Ontario failed, mainly because of frost damage (Zsuffa 1979). However, several selections of native plains cottonwood (*P. sargentii*), balsam poplar (*P. balsamifera*), jackii poplar (*P. x jackii*), and of crosses of these species with other balsam poplar species and hybrids survived and grew very well. Some of these crosses were done by Indian Head Nursery (Cram 1968), and others were selected and hybridized in Ontario. In small trials, on good soils which were properly controlled for weed competition, these clones grew as well as the best clones in south-eastern Ontario. Unfortunately, this programme did not receive support at the time and was discontinued. However, some of the clones, especially those developed by Indian Head Nursery, are readily available and could be used for clonal screening trials. A limited number of the best clones could then be selected for plantation management trials, and eventually for operational planting. In my experience from Northern Ontario, soil quality and site management, in addition to clones, are very decisive factors influencing the success of plantings. Thus, fields with shallow, heavy subsoils, moisture stresses, and weed competition can frequently be causes of failure.

In summary, our experience with hybrid poplar plantations in the boreal forest region is very limited. However, initial clonal stock can be obtained for screening trials and development of proper management techniques. Small scale trials in Northern Ontario have shown that good clonal selections on adequate and properly managed sites can grow as well as anywhere in hybrid poplar plantations. With good support, clones could be selected and management methods established within the next 10 to 15 years.

**IDENTIFICATION AND PROPAGATION OF SUPERIOR PHENOTYPES IN NATURAL STANDS**

Superior phenotypes (plus tree selections) are an important starting point for breeding programmes. Plus tree selections in spruces and pines have been underway for some time now, but the same cannot be said for aspens, cottonwoods and birches. The criteria for plus tree selection and the methods for initial propagation of these species are important considerations.

The criteria for plus tree selection of conifers are well established (Morgenstern et al. 1975). Some of the same criteria (such as age, growth and form of the trees, freeness from pathogens) apply also to hardwood species. However some special considerations will apply as well. In the case of aspen and balsam poplar (black cottonwood), because of root suckering, stand formations could be one clone only or intimate mixtures of very few clones (genotypes). Special attention has to be paid in these cases to select just one tree per clone, because additional selections will be superfluous and misleading duplications. Also, stem decay is an important criterion for aspen: in some healthy-looking aspen trees most of the internal wood could be decayed, and the relationship of this symptom to genotype and environmental conditions (site, age, silviculture) can be very diverse, specific and confusing (Thomas 1968, Basham 1979). Also, some particular pests, such as the bronze birch borer (*Agrilus anxius*) in the case of birch selection, may require consideration.

The propagation of selected trees could be accomplished by grafting, in a similar fashion as in other tree species. Cleft grafting is an often preferred method for hardwood species (Wright 1976). Species which produce root suckers, such as aspen, black cottonwood and balsam poplar, can also be propagated by root-cuttings. Zufa (1971) describes a convenient method of propagation by unearthing and taking pieces of roots from selected trees and producing suckers from the same. Propagation by stem cuttings taken from mature trees in difficult even with
species such as cottonwoods, which otherwise can be propagated easily by stem cuttings. In these species, taking cuttings from young coppices, epicormic shoots or suckers will facilitate the rooting.

IDENTIFICATION OF INFERIOR GENOTYPES IN STANDS AND THEIR REPLACEMENT

We perceive trees in stands as phenotypes, the products of the tree's genotype and its environment. We can usually detect the genotype only after testing the tree's performance in replicated progeny or clonal trials. However, for characteristics which are under strong genetic control and not modified considerably by environment, we can detect the genotype directly by observing these traits on the tree. Some of the traits considered as being under high genetic control are stem form, branching angle, fiber length and wood density. Other characteristics, such as growth, and in many cases resistance to decay and other pathogens, can be influenced considerably by site and age, among other factors. Thus, the identification of inferior genotypes and stands can sometimes be a complicated task, and judgments made on the basis of growth in original stands only can be misleading.

Replacement of species may be needed on some poor sites, regardless of the genotype. This may be the case for replacement of aspen with lodgepole pine on sites considered dry for aspen. The replacement of confirmed inferior genotypes of aspen may require a similar solution. This is because replanting of aspen cut-over sites with other, superior aspen varieties can be a very difficult task (Doucet 1989). It is likely that the roots of logged aspen will sucker, even when scarified and treated with herbicides, and will initially compete with the planted variety. Also, after a few years, the distinction of planted stock from suckers will become increasingly difficult, and the measures needed for cleaning the sucker-competition very expensive. An easier way of replacement will be with a different species, either another poplar species distinguishable form the natural aspen growth, or with a coniferous species suiting the site.

REFERENCES


PROTECTING UNDERSTORY WHITE SPRUCE WHEN HARVESTING ASPEN

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ABSTRACT

This report covers the silviculture component of a joint FRDA-funded project involving NoFC (ForCan), FERIC (West), the AFS and four companies in Alberta. Nine mixedwood stands with understories were scheduled for aspen harvesting in 1988 using a variety of conventional and modified techniques. This report addresses six of these stands.

A brief background on trends in aspen utilization in mixedwood stands with understory spruce is followed by a theoretical two-stage model for tending and harvesting such stands.

Harvesting results — seen as practical tests of the model from a silvicultural perspective — are given in terms of understory damage by cause, yield implications for residuals, and recommendations based on data and experience.

INTRODUCTION

Nature and Extent of Regional Boreal Mixedwoods

The distribution of boreal mixedwoods within four regional Forest Sections (Rowe, 1972) is illustrated in Figure 1. They occupy an estimated 150 000 ha, representing about one-third of the productive forest land base in the prairie provinces. This paper focuses on the white spruce (Picea glauca (Moench) Voss) component of mixedwoods which occurs as an understory with aspen (Populus tremuloides (Michx.), balsam poplar (Populus balsamifera L.) and white birch (Betula papyrifera Marsh.).

Data on the nature and extent of spruce understory stands are not available from current inventories. Recent surveys in Alberta have shown understory stands to be very significant, occupying up to 80% of stands currently inventoried H (hardwood) and HS (hardwood-softwood) (Brace and Bella, 1988, personal comm. D. D'Amico - Blue Ridge Lumber (1981) Ltd.)

NEED FOR UNDERSTORY SPRUCE PROTECTION

Future supplies of commercial white spruce depend in the long run upon successful establishment of new stands, which has proved to be relatively costly and ineffective to date (Drew, 1987, 1988; Peterson, 1989), even though it has been the subject of considerable regional research for many decades on mixedwood sites (Jarvis et al. 1966). In the shorter term, understory stands occurring naturally in association with hardwoods are a primary source of spruce. Until recently, these understories have developed to commercial size through natural succession under the protection of the hardwoods. However, the demand for aspen, which accounts for 80% of regional hardwoods, is rising dramatically, particularly in Alberta (Brennan 1988; Ondro 1989) where over 70% of the aspen AAC has been committed for new and proposed developments by 1993 (Table 1). Many stands inventoried as H and HS are now being scheduled for aspen harvest using conventional harvesting equipment and procedures, jeopardizing the associated spruce understory and the future softwood timber supply.
Table 1. Utilization trends and current AAC - aspen - Western Canada (million m$^3$)

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<th>Utilization Trends$^1$</th>
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<td>.37</td>
</tr>
<tr>
<td>Alberta</td>
<td>.05</td>
<td>.17</td>
</tr>
<tr>
<td>B.C. (Northwest)</td>
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$^1$ Summarized from information provided by provincial governments.


The need for protection of spruce as a component of boreal mixedwoods goes beyond concern for the future commercial softwood timber supply. Concerns also include fisheries and wildlife habitat, aesthetics and recreation, a general dissatisfaction with clearcutting in mixedwoods and a strong interest in mixedwood perpetuation, as expressed recently in 41 public meetings on forestry development in northern Alberta (Concord Scientific Corp., 1989). Also, at a recent forum on the environment organized by the Canadian Pulp and Paper Association (CPPA), industry leaders strongly expressed forest management concerns much beyond timber supply (Addison et al. 1989). There is clearly a need to develop new approaches to mixedwood harvesting, particularly where spruce understories need protection.

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 perpetuate or increase the spruce component of mixedwoods.

**TWO-STAGE TENDING AND HARVESTING MODEL**

Figure 2 illustrates a model which has been designed to accommodate two harvests of aspen in a 120 year cycle and to realize the yield potential of associated understory spruce. The model is described by Brace and Bella (1988). Beginning with an aspen stand aged 60 and understory spruce averaging 40 years of age, the aspen and all spruce over 25 cm dbh could be harvested, leaving a released spruce understory. Sixty years later the mature spruce and a 60-year-old aspen stand which originated from suckers at the time of initial cut could be harvested again and options for future management of the land base considered. The model does not necessarily imply a sustained yield policy for white spruce on this specific land base. The future of the land base - whether hardwood, softwood, or mixedwood - poses many silvicultural challenges, some of which are addressed by Navratil et al. (1989).

**Advantages of the Model**

Advantages of the model would include:

a) reduction or avoidance of the costs and risks associated with establishing and growing spruce on mixedwood cutovers,

b) improved utilization of aspen and increased spruce AAC through increased growth and shorter rotations for spruce released from the understory (tending component of model),

c) maintenance of spruce-related landscape aesthetics, wildlife habitat and recreational values, thereby addressing major shortcomings of the clearcutting model.

![Figure 2](image-url)
system as now practised on many mixedwood sites,
d) contribution to solving the problems created where hardwood and conifer harvesting rights are held by different companies on the same land base, and where protection of understory spruce is a priority for the softwood user.

Disadvantages of the Model

Some of the disadvantages of the model would include:
a) uncertainty about the feasibility of adapting available harvesting technology to protect the understory under a range of stand age, density and site conditions,
b) potential for windthrow of released spruce, particularly on moist sites, as well as the risk of leader-weevil in released spruce,
c) problems with estimating the growth and yield of mixed-species stands of released spruce and new aspen suckers.

GROWTH AND YIELD AND OTHER MIXEDWOOD MANAGEMENT IMPLICATIONS

Brace and Bella (1988) developed growth and yield estimates for spruce released at age 40 and harvested at age 100 in the previous model, for one specific site. Results indicated that if 600 viable 40-year-old spruce residuals survive to age 100 they could yield 550 to 590 m³/ha. Yields would be 10% lower for 400 trees and 30% lower for 200 trees. It is assumed that aspen suckers will occupy any available space in the stand, either as pure clumps or in mixture with spruce, and will supplement softwood yield as spruce stocking declines, up to the yield potential of the site.

After harvesting aspen to release spruce it is not uncommon for a stand to develop separate clumps of aspen suckers and spruce residuals, as well as areas where the species intermix. Because of the variety of conditions possible in such mixedwoods with respect to the density and distribution of species components, growth and yield prediction for spruce and associated hardwoods is difficult, and reliable techniques are not yet available. Such variety, seen as an impediment to growth and yield prediction, is often desirable from other perspectives, for example to provide habitat for particular wildlife species and for landscape aesthetics.

Increases in hardwood utilization, coupled with public demand to maintain mixedwoods for a variety of non-timber purposes are challenging traditional softwood bias in mixedwood management, requiring management objectives beyond softwood silviculture and growth and yield and creating the need for an effective multi-disciplinary approach to both management planning and operations.

FIELD TEST OF THE TWO-STAGE MODEL

Project and Participants

A cooperative mixedwood harvesting project which serves as a field test for the two stage tending and harvesting model was initiated recently under the Canada-Alberta Forest Resource Development Agreement (FRDA). Co-operators include the Western Forestry and Range Management Association (WFRMA), the Alberta Forest Service (AFS), Pelican Spruce Mills (now Weyerhaeuser Canada Ltd. (Alberta)), Weirwood of Canada Ltd., and Millar (1981) Ltd., and Millar-Western Industries Ltd. There are a total of nine study stands, 3 in each of the areas shown in Figure 3. This report addresses the stands harvested in the Drayton Valley area (identified in the report as DC (control), D1 and D2) and in the Hinton area (HC (control) H1 and H2). All nine stands should be completed by April 1990. The final two stands will be harvested during winter to determine the effects of cold weather operation on understory damage. This is particularly important since many sites in the region are only accessible for winter operations.

Objectives

The primary silvicultural objectives of this project were:
a) assess damage to residual spruce trees released during harvesting of the aspen overstory; and
b) monitor subsequent development of the residual spruce (growth, windthrow and weevil risk) and of new aspen suckers (density, growth), and the utility of the approach for addressing non-timber mixedwood management issues.

This report addresses objective (a), emphasizing the residual spruce crop between 2.5 and 14 m high which are the trees most likely to survive and grow to maturity, because they are tall enough to compete with new aspen suckers (Johnson, 1985) and should be reasonably windfirm on upland sites.

Harvesting costs, equipment productivity and details of operational procedures for each stand harvested in the project have been reported by Sauder and Sinclair (1989).
White Spruce Understory

Location of Study Stands
Project - 1480

1 Drayton Valley
2 Hinton
3 Blue Ridge
Procedures and Pre-Harvest Status of Stands

Table 2 describes the harvesting methods and procedures (treatments) applied in each stand. Feller-buncher/grapple skidder harvesting equipment was used in all cases except treatment 2 in Hinton (H2) which used a Swedish shortwood (Rottna) processor and forwarder combination.

Table 3 presents pre-harvest statistics for each stand treated. There were substantial differences between stands in terms of hardwood and softwood overstory composition, volume and quality, average stem size and softwood understory density and distribution. This, combined with the variety of equipment and procedures (Table 2) makes detailed comparisons between stands inappropriate and requires a case study approach based on data and observation.

RESULTS AND DISCUSSION

Controls

Felling and forwarding in stands DC and HC (Table 4) were carried out using conventional equipment, according to prevailing operational ground rules in Alberta, clearcutting the aspen with no concern about understory damage or mortality. No restrictions were placed on the felling sequence or on travel routes for forwarders (skidders). There was apparently a psychological effect of the protection philosophy being applied to other stands, as operators made unusual attempts to preserve some understory spruce clumps. Some spruce were also protected within clumps of non-merchantable hardwood. Control stands are therefore predominantly clearcut, with a few dense understory spruce clumps and scattered individuals and should regenerate primarily to aspen suckers. Control stands primarily used to provide comparative cost and productivity data for the FERIC component of the project.

Felling Mortality and Damage

In general felling caused less mortality but more damage than forwarding in treatments D1, D2, H1 and H2 (Table 4). Felling mortality was minor, varying from 1 to 5%. Felling damage varied from 11 to 19% for feller-bunchers (D1, D2, H1) but was 40% for the Swedish Shortwood Treatment (H2), primarily because the shortwood processor had much less directional felling control than the feller-bunchers. The relatively high initial stand density (1994 trees/ha) may also have been a factor.

Felling damage was recorded mainly as broken tops and branches, bark scrapes on stems, and leaning trees. The Swedish shortwood processor caused a relatively large proportion of bark scrapes and leaning trees. Much of the processor-related damage was minor and would be considered acceptable on residual crop trees.

Large individual spruce, characteristic of many mixedwood stands containing understories, caused considerable damage when hand-felled in treatments D1 and H1. This poses a dilemma in such stands because their high timber value has to be balanced with understory protection priority, blowdown hazard, and need for seed trees when setting treatment objectives.

Equipment-related factors affecting understory damage include size and type of carrier and boom and size and type of felling head. Multiple entries for felling and forwarding also increase damage. These sources of damage can be minimized by matching equipment and harvesting pattern to stand conditions (personal comm. E.A. Sauder, FERIC west). The feller-buncher used in stands D1 and D2 had no boom, so had to approach each tree before felling, increasing understory damage, but it was also relatively narrow, which compensated to some extent for the lack of a boom. The feller-buncher used in H1 had a 3-4 m boom so could reach for trees, but it had a large counterweight which caused damage when turning and a relatively large felling head which caused damage when being positioned for a cut. Both types of feller-buncher carried the trees upright after cutting and bunched them on skid trails, which reduced subsequent forwarding damage and mortality. The relatively good performance of the feller-buncher in H1 was noteworthy, considering the initial understory density (Table 4), reflecting effective planning as well as operator experience and attitude.

The Swedish shortwood processor had a 10 m boom but was unable to take full advantage of it due to the large average size of the aspen being felled (mean dbh 22.1 cm., Table 3) making it necessary to move toward many trees to fell them, resulting in a zig-zagging pattern in the stand rather than maintaining a relatively straight course and reaching for the trees. In addition, it had little directional felling capability and it also caused damage as it shifted felled trees back and forth in a horizontal plane while delimbing and bucking. It had an advantage over the feller-bunchers in being able to swing the felling head above the understory when reaching for aspen, and the smaller felling head caused less damage when being positioned for a cut. This machine would cause much less felling damage if it were operated in a stand where the trees being cut were small enough to allow it to maintain alignment in the stand and take full advantage of the 10 m boom and the smaller crowns of younger aspen would compensate to some extent for the lack of directional felling capability. A large single-grip machine should function more productively.
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Function</th>
<th>Location</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Felling</td>
<td>Drayton Valley (D)</td>
<td>Hinton (H)</td>
</tr>
<tr>
<td>Control</td>
<td>Felling</td>
<td>Feller-buncher on tracked loader with shear head</td>
<td>Feller-bunchers on tracks, with shear head</td>
</tr>
<tr>
<td></td>
<td>Forwarding</td>
<td>Grapple skidders - full tree</td>
<td>Grapple skidders - full tree</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
<td>Conventional clearcut. All species topped, delimbed and bucked on the landing by hand</td>
<td>Conventional clearcut. Stroke delimber and slasher on landing</td>
</tr>
<tr>
<td>Treatment 1</td>
<td>Felling</td>
<td>Same as control</td>
<td>Same as control</td>
</tr>
<tr>
<td></td>
<td>Forwarding</td>
<td>Same as control - full tree</td>
<td>Same equipment as control, but tree length instead of full tree and rub-stumps used along trails</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
<td>Main stand trails located before harvesting and Feller-buncher operator chose other trails. Conifer hand-felled after aspen and skidded separately. All species topped, delimbed and bucked on landing by hand</td>
<td>Main skid trails prelocated and secondary trails flagged before harvesting. Conifer and aspen felled and bunched at same time and limbed and topped before skidding. Oversize spruce hand felled. Stroke delimber and slasher on landing.</td>
</tr>
<tr>
<td>Treatment 2</td>
<td>Felling</td>
<td>Same as control</td>
<td>Rottne double grip processor (fell, limb and buck)</td>
</tr>
<tr>
<td></td>
<td>Forwarding</td>
<td>Same as control (full tree)</td>
<td>Rottne forwarder</td>
</tr>
<tr>
<td></td>
<td>Procedures</td>
<td>Trail designation as in treatment 1. Conifer and aspen machine - felled and thatched down on skid trails by feller-buncher. All species topped, delimbed and bucked on landing by hand.</td>
<td>Highly skilled operators selected trails and controlled operation</td>
</tr>
<tr>
<td>Standard treatment</td>
<td>Area (ha)</td>
<td>Species group</td>
<td>Aspen age (yrs)</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------</td>
<td>---------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Drayton Valley Control (DC)</td>
<td>20</td>
<td>Aspen</td>
<td>110+</td>
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<tr>
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<td></td>
<td>Poplar</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Birch</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spruce</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Drayton Valley Treatment 1 (D1)</td>
<td>20</td>
<td>Aspen</td>
<td>110+</td>
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<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Spruce</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>Total</td>
<td></td>
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<tr>
<td>Drayton Valley Treatment 2 (D2)</td>
<td>15</td>
<td>Aspen</td>
<td>110+</td>
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<tr>
<td></td>
<td></td>
<td>Spruce</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Hinton Control (HC)</td>
<td>18</td>
<td>Aspen</td>
<td>70+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poplar</td>
<td></td>
</tr>
<tr>
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<td></td>
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<td>Aspen</td>
<td>70+</td>
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<td></td>
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<td></td>
<td>Spruce</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
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<tr>
<td>Hinton Treatment 2 (H2)</td>
<td>18</td>
<td>Aspen</td>
<td>70+</td>
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<tr>
<td></td>
<td></td>
<td>Birch</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spruce</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
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</tr>
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</table>
Table 4. Percent Damage to Understory Spruce Trees 2.5 to 14 m During Aspen Harvesting

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Initial N/ha</th>
<th>Undamaged</th>
<th>Felling</th>
<th>Forwarding</th>
<th>Harvested</th>
<th>Other</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Damage</td>
<td>Mortality</td>
<td>Damage</td>
<td>Mortality</td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>550</td>
<td>33</td>
<td>19</td>
<td>1</td>
<td>13</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>HC</td>
<td>1744</td>
<td>13</td>
<td>16</td>
<td>4</td>
<td>14</td>
<td>49</td>
<td>3</td>
</tr>
<tr>
<td>D1</td>
<td>391</td>
<td>44</td>
<td>19</td>
<td>-</td>
<td>11</td>
<td>24</td>
<td>2</td>
</tr>
<tr>
<td>D2</td>
<td>323</td>
<td>65</td>
<td>11</td>
<td>1</td>
<td>9</td>
<td>13</td>
<td>1</td>
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<tr>
<td>H1</td>
<td>740</td>
<td>51</td>
<td>18</td>
<td>1</td>
<td>10</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>H2</td>
<td>1994</td>
<td>29</td>
<td>40</td>
<td>5</td>
<td>(11)</td>
<td>(14)</td>
<td>1</td>
</tr>
</tbody>
</table>

1The Swedish shortwood systems is not directly comparable to others due to the combined functions of felling, delimbing and bucking. Damage and mortality identified as forwarding was not distinguishable from skidder damage but primarily caused by the delimbing and bucking functions. Forwarding effects were minor.

with up to 20% less understory damage, than the double-grip machine used in stand H2 (personal comm. O. Hannula, Weldwood of Canada Ltd.).

**Forwarding Mortality and Damage**

In general, forwarding caused considerably less damage but more mortality than felling in all cases (Table 4). Damage ranged from 9 to 11% and occurred mainly as bark scrapes and leaning trees. Forwarder damage was almost entirely skidder-caused.

Damage statistics for the Swedish shortwood forwarder are misleading because they really reflect the delimbing and bucking functions of the processor as described earlier, but could not be separately identified. The shortwood forwarder itself did minor damage when loading logs - mainly upper stem scrapes - and virtually no damage during forwarding as it was the same width as the processor.

Forwarder-caused mortality varied from 13 to 24% and again was almost entirely skidder-related, since the 14% shown for this Swedish forwarder is really related to delimbing and bucking functions. The good performance of the skidder operation in relatively dense understory in H1 is noteworthy, reflecting effective coordination of the skidder and feller buncher functions, and operator experience and attitude. The 24% skidder related mortality in D1, compared to 13% in D2 in a stand of comparable initial understory density, and 18% for H1 in a stand of relatively high initial understory density is largely a reflection of protection effort, not of equipment.

**The Importance of Protection Effort**

Table 5 summarizes pre- and post-harvest understory spruce density according to degree of protection effort, which was assigned to reflect the planning, layout, supervision and crew experience and attitude which characterized each case. Figure 4 shows that protection effort was more significant than type of equipment used, an observation which is consistent with the results of previous mixedwood harvesting studies (Brace and Stewart 1974, Froning 1980).

**Growth and Yield and Other Management Implications**

If growth and yield data for spruce released at age 40 and harvested at age 100 (Brace and Bella 1988) are applied to the spruce residuals in Table 5, treatment H2 is overstocked and should perform as a relatively pure spruce stand if the trees were well distributed, yielding from 550 to 590 m³/ha, whereas the lower-stocked treatments (DC, D1, D2) should yield spruce in the order of 30% less. Aspen yield would be expected to increase in proportion to spruce yield decrease. These observations are tentative as such growth predictions are currently not well refined, and even assuming they were accurate, their significance could only be judged in terms of management objectives. The lower stocking and yield results would be unacceptable for softwood oriented management, but may be acceptable for mixed-species management. Even without specific objectives for wildlife habitat (e.g., hiding cover, thermal cover and browse for ungulates) or for landscape
Figure 4
Percent Residual Spruce, 2.5 to 14.0m

![Graph showing percent residual spruce vs protection effort.]

Table 5. Residual Crop by Treatment and Protection Effort (trees 2.5-14.0 m)\(^1\)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stems/ha</th>
<th>Post-cut percent</th>
<th>Protection effort(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre harvest</td>
<td>Post harvest</td>
<td></td>
</tr>
<tr>
<td>DC</td>
<td>550</td>
<td>238</td>
<td>43.3</td>
</tr>
<tr>
<td>HC</td>
<td>1744</td>
<td>403</td>
<td>23.1</td>
</tr>
<tr>
<td>D1</td>
<td>391</td>
<td>209</td>
<td>53.4</td>
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<tr>
<td>D2</td>
<td>323</td>
<td>233</td>
<td>72.1</td>
</tr>
<tr>
<td>H1</td>
<td>740</td>
<td>485</td>
<td>65.5</td>
</tr>
<tr>
<td>H2</td>
<td>1994</td>
<td>1181</td>
<td>59.2</td>
</tr>
</tbody>
</table>

\(^1\)Includes undamaged trees and trees with acceptable damage, including broken leader, broken branches, minor bark scrapes and gouges.

\(^2\)Protection effort was subjectively assigned as low, intermediate or high depending upon the combination of planning, layout, supervision and crew experience and attitude in each case.
aesthetics, the treatment results have already been judged by project participants as superior to conventional operations. Such benefits from an understory protection approach to mixedwood management could be more effectively achieved if they were integrated into timber management planning as specific objectives at early planning stages, as recently described by Bonar (1989). Preharvest silviculture prescriptions (PHSP’s) as currently required by law in BC would be an important component of this planning process.

**SUMMARY AND CONCLUSIONS**

1. Mixedwoods are an important regional source of both timber and non-timber resources. There is growing public interest in multiple-use management and increasing criticism of the suitability of current clearcut harvesting practices for that purpose.

2. Stands with white spruce understories are an important component of the mixedwood mosaic, especially in stands inventoried H and HS, and current harvesting practices do not provide adequate understory protection.

3. Recent dramatic increases in aspen utilization are resulting in the allocation of large volumes of aspen in stands inventoried H and HS, jeopardizing a significant amount of spruce understory.

4. This report presents a two-stage tending and harvesting model which should facilitate the release of spruce understories during the aspen harvest and promote the subsequent growth of a new aspen sucker stand while the released spruce are maturing. The model should also reduce or avoid the risks and costs of regenerating spruce on mixedwood cutovers, increase the short-term softwood timber supply, and address some of the inadequacies of clearcut harvesting with respect to integrating non-timber objectives into timber management plans and practices.

5. A recent cooperative field project initiated to test the feasibility of adapting available harvesting technology to protecting understory spruce while harvesting aspen has yielded the following preliminary results:
   a) major improvements in the protection of understory white spruce during aspen harvesting are possible using conventional logging equipment like feller-bunchers and grapple skidders in stands up to 1200 understory spruce per ha (exemplified in treatment H1), and using equipment like Swedish shortwood systems in understory densities of 2000/ha or more (exemplified in treatment H2).
   b) the key to success is *protection effort*, regardless of equipment. It includes:
      i) management objectives set for all relevant resource interests at the stand level, including pre-harvest silvicultural prescriptions (PHSP’s), supported by an adequate stand inventory which includes the amount and distribution of spruce understory.
      ii) selecting equipment and harvesting patterns to match stand and site conditions, thereby minimizing multiple stand entries for felling and forwarding, which are a significant cause of understory damage.
      iii) pre-planning and pre-locating skid trails, landings and protective features like stub stumps in relation to understory density and distribution.
      iv) adequate crew training and supervision, coordination of operators performing different functions, and the attitude and motivation of operators are critical elements in protection, as well as production.
   c) In feller-buncher/grapple-skidder treatments, mortality was most prominent and was mainly skidder-related. Damage was secondary to mortality and was somewhat greater during felling.
   d) Equipment with directional felling capability and the ability to accumulate trees and place them on skid trails is able to substantially reduce both felling and subsequent skidding damage.
   e) In the Swedish shortwood system, damage was most prominent, and occurred mainly during the felling function. Deliming and bucking functions caused less damage but more mortality than the felling function. The forwarder itself caused minor damage and mortality.
   f) Specialized equipment like the Swedish shortwood processor which work reasonably well in stands with a high density understory should be even better if used in lower density understory stands or in stands where trees to be harvested are of a size which will allow the machine to fell all material in one pass to function without deviating from a relatively straight path - i.e., using full boom capability - and where small crown sizes will help reduce felling damage and mortality. A large single-grip machine would probably function with less damage than the double-grip machine used in this project, under similar stand conditions.
   g) Scattered large spruce are a potential major source of felling and skidding damage in these stands. If they cannot be directionally felled, limbed and
topped and skidded log-length consideration should be given to leaving them to provide additional seed for the next spruce crop if they are windfirm.

h) Acceptable spruce residuals must be defined in management objectives, and equipment, planning, training and supervision adapted accordingly. Many aesthetics and wildlife habitat objectives may be met at considerable lower residual densities (i.e., 200 to 400 per ha) than optimum future spruce yield objectives which require 600 or more trees per hectare at age 40.

i) Harvesting costs, equipment productivity and details of operational procedures for this project have been reported by Sauder and Sinclair (1989) and Brace (1990).

j) There is a need for special operating ground rules with respect to utilization in harvesting operations involving the first entry into previously unmanaged stands. It may be best in the long run to leave individual large-crowned trees and to leave merchantable individual trees uncut in clumps of high-value understory in order to prevent severe damage to the residual stand. There is also a need to accommodate selected high stumps (rub stumps) left for purposes of protection along skid trails, and to reassess slash rules as they may relate to equipment such as shortwood processors.

k) Results of this project will be updated over the next 5 years to show the effects of factors such as blowdown and weevil damage, and to monitor actual growth response of both spruce residuals and aspen suckers.

l) The jury on the feasibility of retaining viable spruce residuals when harvesting overstory hardwood is still out - but - there is plenty of evidence in this and other trials that a favorable ruling is possible if both government and industry are committed to such work.
REFERENCES


UNPUBLISHED REPORTS


CURRENT INVESTIGATIONS IN SILVICULTURE

WHERE ARE WE NOW AND WHERE DO WE WANT TO GO IN THE FUTURE?

G. KRUMLIK
MOF - Research Branch
31 Bastion Square
Victoria, B.C.
V8W 3E7

EVERETT B. PETERSON
Western Ecological Services Ltd.,
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ABSTRACT

White spruce has been, until very recently, the major commercial species in the Boreal White and Black Spruce Biogeoclimatic Zone. The silviculture research has therefore focused on regeneration and silviculture of white spruce. Many research projects which have been conducted on white spruce silviculture can be classified under one of the following categories: site preparation (mechanical, chemical, fire, combination), planting stock quality (stock type selection and quality evaluation), studies on competing vegetation (autecology and sylvecology), plantation maintenance and release (chemical and mechanical), herbicide efficacy studies (which herbicide, when, and what rate), and ecophysiology of white spruce (physiological responses to microclimate changes caused by site preparation and vegetation competition).

As aspen and other hardwoods are gaining commercial importance, the base of silviculture research has to become broader and include silviculture of hardwoods. The specific aspects of mixedwood and aspen silviculture to be addressed by research are: identification of ecosystems most suitable for hardwoods; susceptibility to decay and insects, particularly research on aspen trunk rot (Phellinus tremulae); detection of decay; stocking standards; sustainability requirements; growth and yield projections; reforestation requirements for pure aspen and mixedwood types; regeneration response; potential soil compaction and erosion; and identification and promotion of genetically superior aspen clones.

The northern interior of British Columbia has an extensive silviculture research program. The number of silviculture research projects particularly increased since 1985, with the onset of F.R.D.A. Amongst British Columbia’s forest regions, the Prince George Forest Region has the largest proportion of backlog NSR, defined as forest land not occupied by commercial species which until very recently were either spruce, pine or balsam. Most of the past and current research program is therefore focused on spruce silviculture and, to a lesser extent, pine.

The best spruce sites are fresh to moist, medium to very rich. Such sites can support not only excellent spruce growth, but also luxurious growth of herbs, shrubs, and formerly non-commercial trees. In addition, spruce is a late succession species, poorly adjusted to full sunlight at early age and growing slowly in comparison to its competitors. The result is vegetation competition and overgrowth of spruce by undesired vegetation. Aspen is one of the species that regenerates and grows rapidly and outgrows spruce.

Large proportions of the past and existing silviculture research have been directed to remedy this situation, namely to find how to establish spruce on clearcuts and how to control competition of undesired vegetation. Research has
studied all potential methods, including: different methods of site preparation to eliminate existing competing vegetation and to reduce rate of establishment and growth of new vegetation; controlled fire; different kinds of mechanical site preparation; site preparation using herbicides; and combinations of some of these methods, such as browning by herbicides with subsequent burning. Studies on use of different selective herbicides to eliminate competing vegetation in spruce plantations is another large research category. Several studies have been conducted on effectiveness of herbicides on particular competing species, and the influences of timing and rate of application.

Research to date has made it clear that a prerequisite of effective vegetation control is thorough understanding of the biology of competing species. Studies on autecology of competing species were conducted. More recently, studies on competing vegetation complexes were initiated.

Successful reforestation depends as much on survival and rapid growth of planted seedlings as on reducing growth of competing vegetation. Research projects evaluating growth of different stock types were conducted. Methods for evaluating seedling physiological status, vigor, and ability to grow rapidly after planting, have been tested. New methods, such as variable chlorophyll fluorescence, have also been developed.

Recent research studies focused on microclimate monitoring after planting, particularly changes in soil temperature and moisture induced by different site preparations. Increased soil temperature resulted in faster seedling growth and more rapid outgrowth of competing vegetation. At the same time, physiological changes in seedlings were monitored. The tentative results of these eco-physiology studies confirmed that spruce at an early age is not adapted to full sunlight and rapid evapotranspiration. Rapid evapotranspiration resulted in excessive water pressure deficit, closure of stomates, and cessation of photosynthesis. Reduction of light intensity by approximately 30 to 35% was recommended, which corresponds to conditions under an open deciduous canopy.

Results of current research on spruce regeneration indicate that to establish a plantation on a large clearcut it is essential to prepare the site to reduce vegetation cover and to increase soil temperature, to use vigorous high quality planting stock, and to control vegetation development after planting (by using herbicides). The only way to reduce "growth check", which is a slowing down of growth after planting, is by reduction or elimination of the water pressure deficit by reducing light intensity and evapotranspiration. It is evident from these requirements that regeneration of spruce on clearcuts is a complex expensive task that is prone to failure.

Aspen, on the other hand, is an early succession species that readily regenerates on open, moist fertile sites after clearcutting or after fire. Aspen requires full light and early growth is rapid. In British Columbia, until recently aspen was considered a weed species because of inferior wood qualities as compared to spruce. However, in Europe and the Soviet Union aspen has been used for decades. In recent years the North American attitude has changed. Aspen is now used for pulp and for "value added" products, such as waferboard. In Minnesota, aspen sawlogs are cut into lumber and used, after special preservative treatment, in house construction. In northeastern British Columbia, the realization that aspen is a valuable resource happened quickly; at present about 1.6 million m³ is utilized annually by the Louisiana Pacific oriented standoff operation in Dawson Creek.

The change in aspen use and product value brought a need to redesign silviculture research priorities. Land covered by aspen is no longer classified as NSR, and some of the productive forest land may be managed deliberately for aspen rather than spruce. This change brings new research requirements and priorities. The need for new information on hardwood management was reviewed by Peterson et al. (1989). The following discussion focuses mainly on reforestation and silviculture information needs for aspen and mixedwood management.

One of the first decisions to make is which forest sites are best for aspen, spruce, or mixed stands. Refinement of the existing biogeoclimatic ecosystem classification and interpretation of site units for regeneration and productivity are essential prerequisites for optimal use of forest land.

Regeneration of aspen is predominantly by root suckers, which after fire or logging appear in great density and grow rapidly. However, it has been noted that in the Fort Nelson area of British Columbia there is not always vigorous suckering after logging. This could be a result of the naturally cooler soils at that latitude, in combination with the relatively thick forest floor that limits warming of the rooting zone after canopy removal. Such warming is one of the key triggers for sucker formation. The potential unreliability of suckering may make seedling silviculture more important for aspen in the cooler parts of its range than it is further south. More information is needed on the effects of harvest method and harvest timing on suckering density. Site-specific stocking standards for both aspen and mixed stands of aspen and spruce need to be developed.

The concept of aspen as a nurse crop for spruce is often mentioned but the ecological basis for this concept is not well defined. From other regions there is evidence that there is increased weevil damage to conifers after over-
story aspen trees are removed. Aspen is also known to protect understory spruce from late spring frost and from intensive summer sun radiation. For aspen and spruce there is remarkably little information on possible “co-operation” in which both species benefit by the association without the relations being obligatory for survival, or “commensalism” in which one species is benefitted by the association and the other is not affected. Stand-tending practices in mixed stands are not well developed. Guidelines for thinning aspen stands and for spruce release from aspen overstory without causing excessive damage to spruce, although well documented for study sites in Manitoba and Saskatchewan, need to be re-evaluated for sites in northeastern British Columbia. Harvesting of aspen with minimal damage to spruce understory is essential.

A major problem in aspen utilization is decay. At harvesting age, about a quarter of aspen logs are affected by aspen trunk rot (Phellinus tremulae). Reduction of decay and timing of harvest before major decay occurs is critical. Trees must be harvested after they are large enough for utilization, but before decay is well advanced. Optimum harvesting age to maximize yield and log quality and to minimize decay defects has to be determined for specific sites.

A considerable amount of information on growth of aspen has been assembled for various locations within its natural geographic range. However, site-specific growth and yield curves for pure aspen stands and for mixed stands need to be developed for northeastern British Columbia.

Effects of different harvesting methods and timing of harvest on soil, particularly soil compaction, erosion, and changes in humus decomposition rate requires additional site-specific information.

Application of genetic principles to management of natural aspen stands is not well developed. It is evident that some aspen clones possess superior growth, and it is suspected that some of these superior clones may be triploids. Fast growing and high quality clones need to be identified, mapped, and marked in the field. Standards for identifying these high quality clones are needed. Methods for promoting fast growing, high quality clones need to be developed.

Besides the required silviculture research there is a need for innovative wood technology developments. There is a large potential for improved aspen wood utilization, for both pulp and lumber. The development of future directions for silviculture research in northeastern British Columbia has to take into account the new perceptions of aspen use. Instead of considering aspen as a weed or as an obstacle to spruce regeneration, aspen is gradually gaining equal status with spruce. For this reason, future research has to be directed toward aspen and mixedwood silviculture, toward developing methods for growth of high-quality aspen stands, and toward growth of mixed stands in which aspen will serve as a nurse species for spruce.

REFERENCE

THE FUTURE FOR MIXEDWOOD MANAGEMENT IN B.C.

JOHN CUTHBERT
Chief Forester, B.C. Forest Service

ABSTRACT

In northern British Columbia hardwoods represent a substantial portion of total forest biomass and occupy in excess of 2 million hectares. Integrated resource planning is essential to resolving conflicts and to ensuring that development of the mixedwood forest resource is compatible with a range of resource values. Development of new approaches to integrated resource planning and resolving conflicts is the key to future development of our northern mixedwood forests.

Mixedwood forests of the future will differ substantially from our present stands. In the future, management of mixedwood forests must involve more than just cutting and allowing natural regeneration of hardwoods if we are to meet our timber supply commitments and integrated resource management objectives. Research is required in many areas to support development of management prescriptions, to develop and test alternative approaches to mixedwood management, and development of decision support tools to aid in resolving land-use conflicts.

BRITISH COLUMBIA'S MIXEDWOOD FOREST RESOURCE

British Columbia's hardwood forests represent 3.4% of Canada's total forest biomass and 17% of Canada's total hardwood biomass. Poplars (aspen, balsam poplar and cottonwood) represent approximately 6.4% of the total forest biomass in B.C. while all hardwoods total 8.4% (Bonnor 1985). Much of our poplar biomass is concentrated in northeastern B.C. In the Fort Nelson Timber Supply Area (TSA) 36.9% of net mature volume is hardwoods and in the Fort St. John and Dawson Creek TSA's 21.5% of net mature volume is hardwoods (Peterson et al. 1989). In these 3 TSA's the gross deciduous land base covers approximately 2 million hectares.

Interest in and utilization of aspen in B.C. has increased rapidly over the past few years. In the future we can expect further increases in utilization of aspen and hardwoods in response to: increasing world fibre demands; technological developments which improve our ability to utilize hardwoods; public interest in the use and management of forest resources; and, costs, problems, and controversy associated with conversion of hardwood forests to coniferous forests.

NORTHERN MIXEDWOOD MANAGEMENT ISSUES

Utilization of hardwoods provides new opportunities for employment and industrial development in northern B.C. However, increased utilization of this forest resource will create increased pressure on deciduous and mixedwood stands in northeastern B.C. with the likelihood of increasing conflicts with other resource users.

Resources in our Northern Mixedwood forests include: Agriculture (Range); Energy; Minerals; Fisheries; Forestry; Heritage and Cultural; Recreation; Water; and Wildlife. Resolving land-use conflicts is a priority issue in the management of northern hardwood and mixedwood forests (Petersen et al. 1989). In many places multiple tenures already exist, for example in some areas grazing permits, guide and outfitters licences, and pulpwood agreements share the same area.

Achieving integrated resource management in our mixedwood forests requires a systematic approach. The B.C. Forest Service is working with other agencies to develop an integrated resource planning system to assist in resolving conflicts and in developing long-term integrated resource management plans for managing forest areas.
With appropriate management we can enhance the diversity and value of our hardwood and mixedwood forests. Young aspen stands provide a valuable food resource for moose, deer, and hares and provide cover for small mammals and songbirds. Young and mature forest stands provide cover and shelter for wildlife. Cattle can graze in young aspen stands.

Effective management will involve developing site specific management prescriptions and plans which consider stand level and forest level management objectives and which include: species selection, site preparation, brushing, and stand tending practices. At present we manage stands based on their composition prior to harvest, working towards maintaining leading coniferous and leading deciduous stands. In the future, good management practices will require that we manage for hardwoods as well as softwoods on a site specific basis.

We must ensure that our move into mixedwood management is indeed one involving conscious decisions and not one of accepting what we get by default. As Drew (1988) suggests for Alberta, a laissez faire attitude to mixedwood management - "regenerate extensively and live with what you get" - will result in future forests which will be less suited to meeting either sustained yield or multiple use objectives.

Refined tools are needed to assist in selecting appropriate treatment and management options. The Ecosystems approach provides a useful basis for making ecologically sound, site specific decisions.

A recent field guide for seral aspen ecosystems of one variant of the Boreal White and Black Spruce Zone (BWBScl) (DeLong 1988) includes reference to suitability of sites for hardwoods, softwoods, agriculture, and range uses. Costs, desired products, local wood supply commitments, and other resource values must also be considered in selecting a management approach. Because of the number of factors which must be considered and the interaction between factors, future decision support tools will likely rely heavily on emerging computer technology, particularly simulation models and geographic information systems (GIS). The ecosystems approach provides a good foundation for this work.

Opportunities for mixedwood management at the stand and at the forest level have yet to be fully explored. At the stand level a deciduous component may improve nutrient availability, increase forage availability for wildlife and cattle, and provide a nurse crop to reduce frost damage to conifers. However, too much deciduous cover will reduce conifer yields.

We need to try new approaches in managing mixedwood stands. Practices such as managing spruce regeneration in the understory of aspen stands (Brace and Bella 1988) may be useful in areas where frost or competing vegetation create problems for regenerating white spruce.

At the forest level we must be concerned with supply commitments and with integrated resource management objectives. Using integrated resource planning we can work towards creating a mix of stand age classes and composition within individual watersheds or forests to maintain or enhance wildlife habitat while reserving key areas such as critical winter habitat.

THE FUTURE

Achieving effective management of our mixedwood resource requires planning activities at the stand, forest, watershed, TSA, Region, and Provincial levels. A substantial body of information and advanced decision making tools are needed to assist resource managers. Further technological developments are needed in harvesting and processing to increase utilization of aspen in B.C.

At present the B.C. Forest Service is acquiring much needed information and is working on approaches to assist in management decision making. We are firmly committed to the wise integrated management of our northern mixedwood resources. Much of the current hardwood AAC of nearly 2 million m³/yr which covers 950,00 ha in the Dawson Creek and Fort St. John TSA's is committed or soon will be. In addition, private land holdings will become increasingly important in the development and management of northern mixedwood forests.

We expect that future hardwood stands will differ substantially from present, mature stands. We are planning to harvest our current deciduous stands to create an age class distribution which will maintain or improve yields. In the Dawson Creek TSA initial harvest of older age classes of aspen will be accelerated to levels above long range sustained yield (LRSY) levels to permit use of these stands before their value declines further and to create new stands where decay and stain problems will be substantially reduced (Figure 1). In contrast, in the Fort St. John TSA the inventory is younger and utilization will start at LRSY levels.

Increasing utilization of the mixedwood resource is providing new economic opportunities in northern B.C. In addition, it provides an opportunity for the forestry community to look at new approaches to integrated resource
management planning while ensuring the sustainable development of our northern mixedwood forests.

CONCLUSIONS

Our northern mixedwood forests are a valuable resource. Strategic planning is required to ensure effective management and sustainable development of our mixedwood forests. Our management of northern mixedwood forests must consider wildlife, agriculture, recreation, forestry, and other resource values and must be directed towards achieving integrated management while meeting timber supply commitments.

Management of mixedwood forests must involve more than just cutting and allowing natural regeneration of hardwoods. We must make conscious decisions for the regeneration and silviculture of coniferous, deciduous, and mixedwood stands if we are to achieve our integrated resource management objectives. We must work together in developing solutions to key problems and issues in the management of our mixedwood resources.

![Graph showing deciduous harvest forecast for the Dawson Creek and Fort St. John TSA's.](image)

Figure 1. Deciduous harvest forecast for the Dawson Creek and Fort St. John TSA’s.

LITERATURE CITED


CLOSING REMARKS BY KEN W. PENDERGAST,

Chairman Northern Mixedwood '89
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Ladies and gentlemen, we have concluded the technical session for this Northern Mixedwood '89 Symposium.

The objective of the Steering Committee was to have speakers present technical papers to reflect the current knowledge and experience available in Europe and North America pertaining to mixedwood management. Topics covered in day one were:

- World market conditions
- Mixedwood management decisions pertaining to:
  - Inventory
  - Ecology
  - Regeneration
  - Harvesting technology
  - Pest management
  - Integrated use
  - Economics

Today, we have had an opportunity to hear from our Soviet and Scandinavian friends, the challenges they face in harvesting mixedwood due to social and economic trends, utilization and market demands. As such, we have learned there are wide parameters in both utilization and hauling distances dependent on economic needs.

This afternoon was dedicated to research and silvicultural enhancements and future needs to cope with mixedwood management. The future of mixedwood management in British Columbia has been summed up by our Chief Forester, indicating that with the new markets and interest in our forests, the opportunity for industry is very strong and forest managers have to remain proactive to remain competitive.

I believe all speakers are to be commended on their talks. The information was presented in a format useful to forest managers. Those practitioners can now take the information received over these past two days and apply the experience and research to their forest areas.

However, we must recognize that our objectives were intentionally ambitious, and that we have a long way to go in securing the total answers to mixedwood management. We have uncovered the tip of the iceberg, and only continued experimenting and associated research will provide the answers to the many questions in our minds. Our Minister of Forests indicated during his talk, the opportunity for future symposia of this nature, to assist in this regard.

As Chairman of the symposium, I want to thank all the speakers for their excellent presentations. I would like to also thank each and everyone of you people for attending and making our symposium in Fort St. John the success that we feel it is. I look forward to participating in another Mixedwood Symposium in a couple of years, after we have had the opportunity to broaden our experience base through the information and research initiatives.

We have good participation planned for the field day tomorrow in both the Dawson Creek and Fort St. John Forest Districts' Demonstration Forests. The team approach to evaluating these sites with the expertise at hand is sure to present some valuable pre and post harvest prescriptions that can be considered for our local forest management decisions.

I wish everyone a prosperous year and a safe journey home. Thank you. Have a great day.
APPENDIX I

SUMMARY OF COMMENTS, SUGGESTIONS AND CONCERNS
AS A RESULT OF THE NORTHERN MIXEDWOOD '89 FIELD DAY
APPENDIX I

SUMMARY OF COMMENTS, SUGGESTIONS AND CONCERNS
AS A RESULT OF
THE NORTHERN MIXEDWOOD '89 FIELD DAY

COMPiled BY
MICHAEL C. PEDERSON

1. Timber Supply Area objectives are required to determine:
   • what level of coniferous AAC is to be maintained.
   • what will be the impact on both the coniferous and deciduous AAC’s if we are not managing for either pure spruce or pure deciduous types.
   • what it is exactly that we want to grow on our mixedwood sites.

2. An overall management strategy should be developed concentrating on coniferous—deciduous management conflicts before extensive logging in the mixedwood types occurs.

3. An updated and accurate inventory is essential to make intelligent management decisions. The method of assessing the inventory should be sensitive enough to detect spruce understory under aspen and differentiate between aspen and balsam poplar.
   • the present inventory indicates aspen as the leading species in types where spruce is now the leading species. Are aspen LRSY’s overestimated?
   • balsam poplar stands labeled as aspen will impact on the type of deciduous manufacturing facilities required.

4. Growth and yield information in the Peace River area on conifers, deciduous and mixedwood is poor. This situation must be improved upon before the AAC is fully committed.

5. A stand should be managed for either coniferous sawlogs or deciduous fiber, but not for both at the same time, following harvest.
   • there is a high cost associated with harvesting aspen while protecting the spruce understory (made up of both spruce mortality due to logging damage and the added cost of maneuvering fallen aspen to protect the spruce).
   • 2 or 3 species with different rotation lengths within the same stand represents a cost that would be greater than any benefits arising from the practice.

6. All sites visited had options for either coniferous, deciduous or mixedwood management. The choice of options varied on:
   • personal viewpoints.
   • timber supply requirements.

7. The British Columbia Biogeoclimatic Ecological Classification System may not, in its present form, be a useful tool to predict mixedwood productivity. On the tour, all sites were zonal with a range of poor to average for predicted aspen productivity.

8. More research needs to be funded into mixedwood logging, of natural mixedwood stands, to minimize understory damage.

9. Attempts should be made to create better wildlife and aesthetic conditions by utilizing smaller cut block sizes. These smaller cutblocks should offer a diversity of cover, if they are a mixture of deciduous and coniferous blocks.

10. Will the provincial government allow reduced stumpage in a selectively logged area, or under a two-pass system for aspen and spruce?
   • this would work if the licensee had a fully integrated operation.
   • separate licensee’s with overlapping tenures (i.e. one coniferous and one deciduous) would usually not look after each other’s interests.
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