forestry report

No. 29 (April 1984) Northern Forest Research Centre Edmonton, Alberta

Growth, yield, and ENFOR

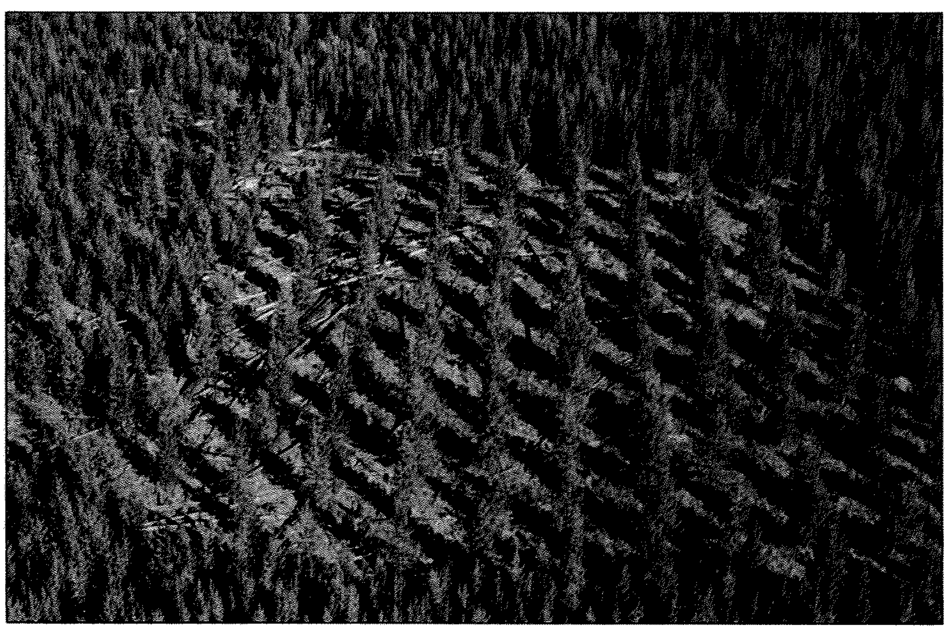
Increasing public awareness about the state of forestry and concerns about present and future wood supplies are bringing about an intensification of forest management across the country. There are already local shortages of economically accessible timber, and these shortages will become more acute and widespread unless remedial action is initiated now. Although the prairie region, particularly Alberta, now has a timber supply surplus, pressures for alternative land uses on accessible reserves are increasing. In addition, escalating transportation and other logging and milling costs provide strong incentives for improving timber yields and increasing tree size on better-quality sites with secure tenure near processing facilities.

The Northern Forest Research Centre (NoFRC) already has collected a great deal of useful information on species selection and spacing of plantations, precommercial thinning effects, and response to fertilization — treatments that under certain conditions can result in doubling of merchantable timber harvest yields. The first half of this report therefore highlights some of our current results using these intensive silvicultural techniques and gives a preview of our effort in developing quantitative (mathematical simulation) models to accurately forecast the outcome of such treatments and updating forest inventories.

While intensification of forest management is the key to the present and future viability of forestry, it is also important in providing substantial employment opportunities in this recession-prone industry, noted for its boom-and-bust cycle. Proper planning by forest managers and appropriate government incentives can do much to alleviate unemployment during recession by increasing much-needed reforestation and stand improvement efforts. Such a strategy would also allow some easing-up on these activities during boom periods of high labor demand and escalating labor costs.

The second half of the report gives a summary of the ENergy from the FORest (ENFOR) program in this region. The ENFOR program of the Canadian Forestry Service was established in 1978 as part of a federal interdepartmental effort to develop renewable energy sources and reduce our dependence on oil as a primary energy source. Its mandate is to support the research, development, and demonstration of new methods and technology necessary to provide for a significant increase in the contribution of forest biomass to Canada's primary energy production. Presented in this report are brief outlines of some current contract studies that have been completed or are in progress: biomass content of tree species by component; biomass availability in the region; biomass harvesting with integrated utilization in poplar stands; and nutrient budgets in poplar stands, particularly as they relate to total utilization of aboveground biomass on a short rotation.

Imre Bella



Thinning of lodgepole pine.

Suggested Reading

Reed, F.L.C., and Associates Ltd. 1978. Forest Management in Canada, Volume 1. Environ. Can., Can. For. Serv., For. Manage. Inst. Petawawa, Ont.

In this issue:

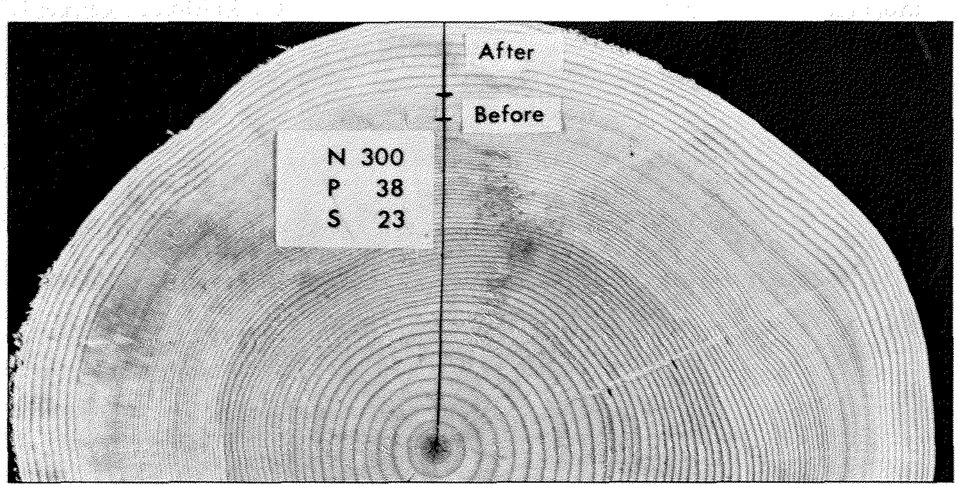
Growth, yield, & ENFOR

Fertilization of lodgepole pine in Alberta improves stand growth

Forest fertilization provides an opportunity to improve yields where the limiting factors are soil nutrients rather than other environmental factors such as moisture or temperature. For effective fertilization that produces the best financial return, the forest manager needs to know the kind, quantity, and timing of each treatment for a variety of stand conditions.

The key to successful forest fertilization consequently lies in accurate diagnosis of nutrient deficiencies and correct prescription of nutrient requirements for the stand. Three main diagnostic techniques are available for foresters: soil analysis, foliar analysis, and field trials.

Soil tests and plant analyses together are most commonly used for diagnosing the need for fertilization of agricultural crops. The use of soil tests for diagnosing the need for fertilization of forest trees has met only limited success, however. It is difficult to obtain representative soil samples from the tree's rooting zone and to estimate the available-to-tree fraction of soil nutrients.



Stem section showing the effect of fertilization with N at 300 kg/ha, P at 38 kg/ha, and S at 23 kg/ha.

Foliar analysis is a potentially powerful technique in evaluating possible nutritional needs. It both reflects what is available in the soil and indicates the amount taken up by the tree. Field trials provide ultimate proof of the

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Growth models for yield forecasting in aspen and jack pine

Intensive forest management requires accurate estimates of current growing stock and future growth and yield under different conditions and treatments. An inventory is generally the first step. Once it has been completed for an area, it is seldom practical to reinventory the forest every time current information is required.

When available, yield tables were used in the past to update inventories and forecast yields, although their application was limited to a somewhat narrow range of stand conditions.

In the last 10-15 years, advancements have been made in forecasting growth and yield through the development of forest growth simulation models. The advent and general availability of high-speed, large-capacity computers made this possible.

These models are generally based on individual tree growth and mortality relationships. In the models, each tree is described by its major size parameters (i.e., stem diameter, height, and crown width or length), from which volumes to any merchantable standard or weight by component can be estimated. The development of each tree is projected individually, and with suitable equations stand statistics are obtained simply by summing individual tree statistics per unit area.

Although stand growth simulation models are quite varied in their structure, scope, and utility, they have been classified into two main categories:

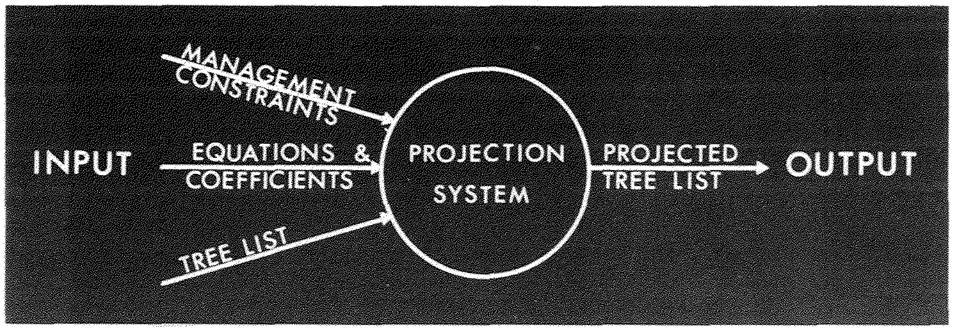
- **distance dependent** models, in which each tree is described by spatial coordinates used for realistic evaluation of intertree competition, and
- **distance independent** models, in which crowding effects are described indirectly from tree size and stand statistics.

NoFRC is currently testing STEMS (Stand and Tree Evaluation and Management System), a growth model developed at the North Central Forest Experiment Station of the U.S. Forest Service for species and conditions that also occur in our region. In our tests based on local data, the model gave satisfactory growth and yield estimates for aspen and jack pine. Work is in progress to calibrate it for lodgepole pine and white spruce.

STEMS is an individual tree, distance independent model that can provide much useful information about trees and stands. It is quite general, and coefficients for its principal functions have been developed for all the major tree species of the Lake States. The model has the potential to evaluate different silvicultural treatment outcomes (e.g., in spacing, thinning, and fertilization), and it also has the potential for growth projection of multispecies stands. As trees are "grown" individually, the user can tailor output to his objectives.

Despite its complexity and broad scope, the model when calibrated has rather modest input requirements that include tree diameter at breast height, age, site index, and crown ratios; the latter can be estimated if not available. It is anticipated that the model's main uses will be in updating forest inventories and forecasting the outcome of different silvicultural treatments.

Imre Bella



Schematic diagram of STEMS.

Fertilization

Continued from page 2

benefits of fertilizer treatments in terms of extra yield, but they are costly and lengthy.

Fertilizer trials in this country have been conducted mainly in eastern Canada and on the west coast. Limited published results for the prairie provinces indicate that pines respond favorably to fertilization. Nitrogen fertilizer improved the growth of jack pine stands on medium sites in Manitoba and of mixed black spruce and jack pine stands on poor sites in Saskatchewan. A 72-year-old lodgepole pine stand on medium quality sites in west-central Alberta that was thinned and fertilized in 1968 also responded favorably to N treatments (Bella 1978). Applications of 112-673 kg/ha of N increased gross production by 7 m^3/ha and merchantable volume by 8 m^3/ha (i.e., 27% and 31%) in a 7-year period.

Lodgepole pine plays a major role in Alberta's forest industry and is increasing in importance. As a result, a larger study was initiated in 1970 in west-central Alberta to explore the effects of N, P, and S fertilization on tree and stand growth on two site types and two age classes and to examine the usefulness of using foliar contents, soil characteristics, or their combination as a diagnostic tool for fertilization. A total of 19 fertilizer combinations were applied to 30- and 70-year-old stands on Coalspur (Orthic Gray Luvisol) and Mercoal (Podzolic Gray Luvisol) soils.

The 10-year results in the 70-year-old stand showed improved growth of lodgepole pine after N, P, and S fertilization on these two soils. The merchantable volume of the stands increased an average of 28 m^3/ha, or 47%, on Mercoal soil and 33 m^3/ha, or 48%, on Coalspur soil. While the effects of P and S on lodgepole pine growth were inconclusive, the effect of added N fertilizer on the stand growth was substantial and consistent.

In general, field trial results to date suggest that fertilization could be a potentially useful treatment for managing lodgepole pine in Alberta, but many technical, economic, financial, and environmental questions related to forest fertilization in this region remain unanswered. Continued research to obtain answers to these questions is a priority before forest fertilization becomes operational.

Richard Yang

Reference

Bella, I.E. 1978. Fertilizing after thinning 70-year-old lodgepole pine *(Pinus contorta* Dougl. var. *latifolia* (Engelm.) in Alberta. Environ. Can., Can. For. Serv. Bi-mon. Res. Notes 34(4):22-23

Red pine outgrows jack pine in southeastern Manitoba

As forest regeneration by planting increases across Canada, species selection and the spacing of trees at the time of planting emerge as important considerations. In southeastern Manitoba, jack pine and red pine have been planted extensively for nearly two decades. Study plantations of these species established in 1963 in the Sandilands Forest Reserve by the Canadian Forestry Service in cooperation with the Manitoba government are already providing useful information on tree growth and development at different spacings.

Four spacings (1.2, 1.8, 2.4, and 3.0 m apart) in 11 x 11 matrixes (121 trees) were planted with four replications on fresh, sandy, nutritionally poor soils, which represent medium-quality sites in the area.

Fifteen years after planting, tree basal area increment at wide spacing was more than double that at narrow spacing, which gave rise to substantial differences in average diameter. After slower initial growth, red pine has had accelerated basal area increment at all spacings during the last 5-year period and has caught up to jack pine in average diameter at breast height (dbh), at wider spacing surpassing it.

Height increment in red pine was not affected by spacing, although the highest increment occurred at medium spacing. In jack pine, height increment declined with wider spacing; the reduction was about 30% between the two extreme spacing levels (1.2 and 3.0 m).

Poor tree form developed in jack pine at wide spacing (3.0 m), resulting in heavy branches, irregular crowns, and multiple leaders. Red pine showed few adverse effects from open spacing, although it retained full crowns to ground level.

Stand productivity — whether in basal area, volume, or biomass — was highest for both species at the closest spacing, but the continued faster growth at wide spacing means that the difference will be reduced or even eliminated by rotation age. Mortality was generally low.

Several conclusions can be made to date:

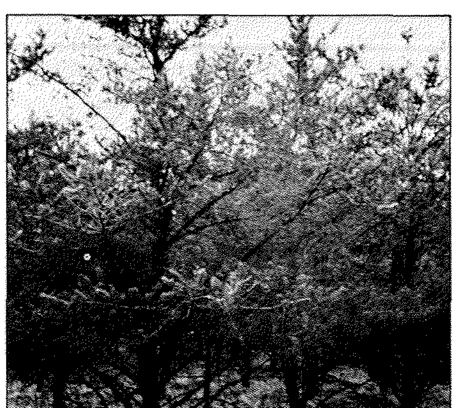
1. Jack pine should be planted at spacings between 2.0 and 2.5 m if reasonably good tree form is an objective.
2. Red pine generally retains good tree form and can be planted at any spacing to fulfill particular management objectives.
3. For planting on average or better sites in southeastern Manitoba, red pine should be favored over jack pine.

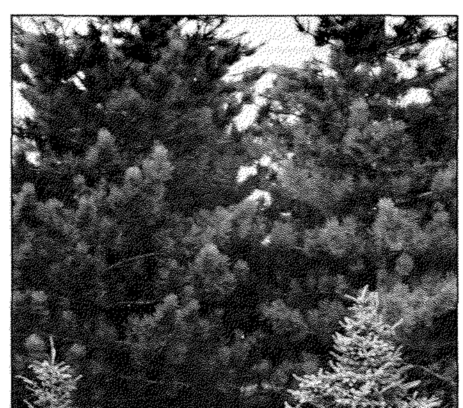
Further details of this study are available in Information Report NOR-X-223, *Spacing effects 15 years after planting three conifers in Manitoba.*

Imre Bella

Spacing effects 15 years after planting

Spacing (m)	Avg dbh (cm) Jack pine	Red pine	Avg height (m) Jack pine	Red pine	Basal area/ha (m^2) Jack pine	Red pine
1.2	6.0	6.0	5.55	4.07	19.71	20.82
1.8	7.9	7.8	5.78	4.44	14.98	14.56
2.4	9.3	9.9	5.56	5.11	11.55	13.32
3.0	8.7	9.6	4.67	4.66	6.61	8.18





Jack pine (left) has poor form and heavy branches at wider spacing in contrast to red pine (right). White spruce in the foreground (right photo) is the same age as the pines, 20 years old.

Summary of Alberta spacing and thinning studies in lodgepole pine

Treatment	Age at last measurement (yr)	Optimum spacing tried (m)	Mean tree Dbh (cm)	Mean tree TV[a] (dm^3)	Mean tree MV[b] (dm^3)	Optimum improvement over control (%) Dbh	Optimum improvement over control (%) TV	Optimum improvement over control (%) MV	Stand volume (m^3/ha) Total Treatment	Stand volume (m^3/ha) Total Control	Stand volume (m^3/ha) Merchantable Treatment	Stand volume (m^3/ha) Merchantable Control
Spacing at stand age 7 yr	25	2.25	8.6	19	N/A	50	140	N/A	32	43	22	4
Spacing at stand age 25 yr	35	2.25	10.8	N/A	N/A	25	N/A	N/A	85	200	N/A	N/A
Precommercial thinning at stand age 22 yr	47	1.8-2.4	15.0	74	44	20	210	<1000	140	160	73	17

[a] TV = Total volume.
[b] MV = Merchantable volume.
[c] In spaced stands, improvement over closest spacing.
N/A = not available.

Spacing is the key to improved yields in lodgepole pine

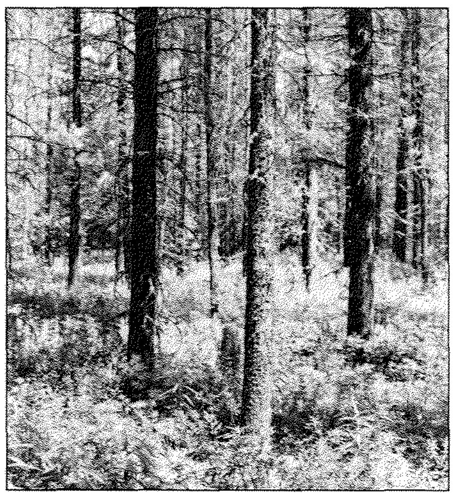
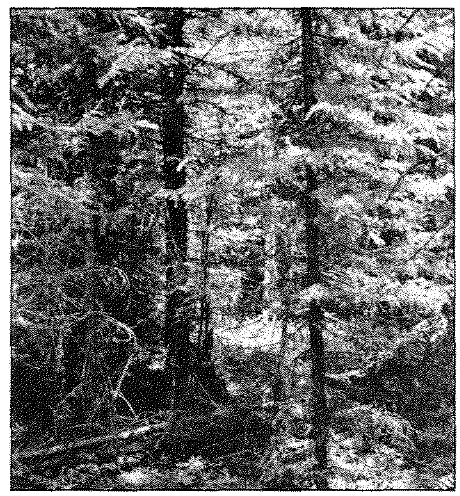
Lodgepole pine commonly forms overdense stands following wildfire or scarification in recently cutover stands, which results in reduced tree growth and lower merchantable yield. Reducing density through spacing or precommercial thinning can ensure continued rapid tree growth and improved merchantable timber production. Two spacing studies and a selective precommercial thinning study in young, overdense, fire-origin stands in west-central Alberta were begun over a decade ago and are now providing growth and yield information over a range of spacing densities.

The first spacing study was established in 1963 in a 7-year-old stand south of Hinton (on the Gregg Burn). The second study was set up in 1967 at Tepee Pole Creek in a 25-year-old stand. Five spacing levels included densities from 500 trees/ha (4.5 m spacing) to 7900 trees/ha (1.1 m spacing). Both studies covered low, medium, and good sites.

The selective precommercial thinning trial was established in 1954 in a 22-year-old pine stand near McKay. Four density levels (750, 1700, 3000, and 4300 trees/ha) with suitable control plots were established on somewhat better than average sites. In contrast to the two former studies, no attempt was made here to conform to rigid spacing. Rather, emphasis was on leaving the most vigorous trees, while maintaining fairly uniform stocking over the area.

A number of trends have emerged. The best spacing for optimum diameter and height growth and merchantable stand volume production was 2.0 to 2.5 m (i.e., between 2500 and 1600 trees/ha). The tables show the gains that can be expected at such spacings.

The influence of spacing on height increment and mean height (not shown in the table) was relatively small and inconsistent. Height growth was least at the widest (4.5 m) and closest (1.1 m) spacings and in the control stand. No doubt, height increment also would be greatly reduced in overdense, stagnating stands, which were not sampled in these studies. In general, lodgepole pine seems to require some degree of crowding for maximum height growth.

A 47-year-old lodgepole pine stand thinned (left) to 1.8 m spacing in 1954 at age 22 and unthinned (right).

Regular mortality generally declined with wider spacing, but irregular mortality from various causes between ages 15 and 25 years emerged as a problem, especially on some better sites.

Although costs tend to be lower with early treatments (between ages 5 and 10 years), these results suggest that treatments may be delayed to age 20 without much reduction in tree growth and vigor. This allows time for the trees to express dominance and pass through the period (15 to 25 years) when heavy mortality losses may result in understocking and serious reduction of yield at wider spacing.

The ultimate benefits of spacing and precommercial thinning can be assessed only at harvest, which is at least another 15 years away for even the oldest of these studies. Related results from other general growth and yield investigations, however, indicate that stands of around 2500 trees/ha at age 20, on medium sites, should have pulpwood yields just about double those of stands of 10 000 or more trees. The relative gain in yield would be even higher on poor sites; good sites, with somewhat lower relative gain, would have the greatest absolute improvement in pulpwood yield. While such density (i.e., 2500 trees/ha) would not maximize sawlog production, it would likely enhance sawlog quality through smaller knot size and reduced taper and would provide a good reserve of vigorous trees to replace mortality or allow a commercial thinning.

Further details of these studies are available in Information Report NOR-X-236, *Effects of spacing 7-year-old lodgepole pine in west-central Alberta;* NOR-X-237, *Precommercial thinning speeds growth and development of lodgepole pine: 25-year results;* and NOR-X-244, *Juvenile spacing of 25-year-old lodgepole pine in western Alberta.*

Imre Bella

Integrated utilization makes aspen an economic resource

Aspen's high incidence of decay and the resulting high cost of its products have made it uncompetitive compared to the more desirable softwoods. In order to compete on the open market, aspen wood products must be cheaper than softwoods, but therein lies the problem. Harvesting easily accessible, better-quality stands and using improved harvesting techniques could make aspen products economic.

An aspen utilization study was conducted in 1982 featuring harvesting and milling of 212 cunits of aspen from three stands that were 56, 82, and 100 years old (labeled young, mature, and old; 5 acres in total) at Slave Lake, Alberta. Veneer, dimension lumber or studs, and waferboard were produced using local equipment and work force. The stands were 90% aspen and 10% balsam poplar. There was an unexpectedly high 18% cull volume in the young stand, 6% in the mature, and 13% in the old stands. Heart rot was present mainly in the old stands, while crooked logs were a problem in all three stands.

Veneer

The best-quality logs were used as peelers, which bring the highest price. The greatest proportion of potential peelers, about 35%, came from the old stand and had large average stem size and relatively good form. About 19% and 17% of peelers came from mature and young stands. Approximately 32% of the peeler logs in young stands and 12% in mature stands were balsam poplar.

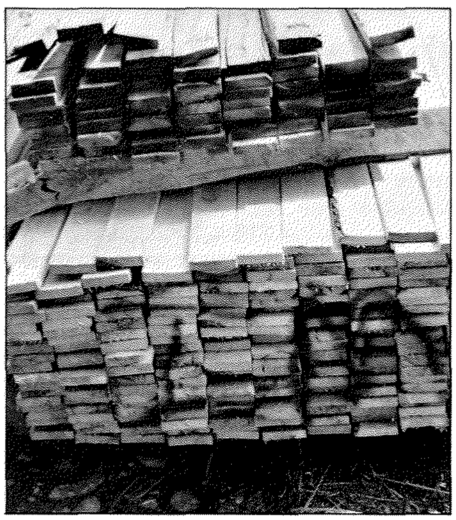
The veneer (1/16 in. basis) recovery was highest from the mature stand, 5015 sq. ft./100 cu. ft.; however, the average recovery for the three stands was 60% less than would be expected from peeling spruce and pine.

Half of the bolts from the old stand did not reach the minimum peeler log size (9-in. top diameter) due to butt rot or interior defects such as spiral grain, ring shake, or interior rot, which were the main causes of partial peeling. About 30% of bolts from the mature stand and only 6% of bolts from the young stand were peelers. Peeling was done in the spring; the high temperatures needed to thaw frozen bolts in the winter can cause fiber breakdown under the pressure of the veneer knife. There was little butt rot in the bolts from the mature and young stands. Cores, veneer bolt rejects, and sawlogs were processed in the stud mill.

Lumber and studs

Logs for dimension lumber and studs were limbed to a 5.5-in. top diameter, and logs with excessive crook or sweep were bucked with a chain saw to improve sawlog recovery. The highest rate of lumber production, 98 fbm/min (foot board measure per minute), came from the mature stand and was followed by 39 fbm/min and 65 fbm/min from the old and young stands. Lumber recovery was highest from the old stand (529 fbm/100 cu. ft.) and lowest from the young stand (422 fbm/100 cu. ft.). These values are about 20-40% less than those for sawing softwoods (723 fbm/100 cu. ft.).

Dimension lumber and studs were planed in the spring, after which they were trimmed and graded according to SPF (spruce-pine-fir) specifications. Planing was difficult because the high moisture content of the shavings caused plugged blowers. The highest recovery and throughput was 145 fbm/min from the mature stand, followed by 95 fbm/min for the young stand and 57 fbm/min for the old stand. The greatest higher-grade recovery came from the mature stand, as shown in the table. In comparison, recoveries from softwoods can reach 93% for construction-grade 2 x 4s.



Lumber from aspen.

Waferboard

Tree-length logs for waferboard production were delivered to the mill yard, where they were spread, bucked to 8.5 ft., stacked, and scaled. The mill reported waferboard (3/8 in. basis) recovery of 1325-1467 sq. ft. per 100 cu. ft. roundwood input.

Waste

The total weight of residues from the veneer and stud mill was obtained by deducting the weight of the veneer and studs from the weight of logs. These residues amounted to 76%, 71%, and 77% of the total weight for old, mature, and young stands. All waste material is potential feedstock for energy related uses.

Economics

In 1982, spruce-pine veneer (1/16 in. basis) sold for about $17 per 1000 sq. ft. According to industry sources, aspen veneer (1/16 in. basis) sells for about a 15% lower price, at $14.50 per 1000 sq. ft. The average 1982 mill net price for spruce-pine studs was $169 per 1000 fbm, while aspen studs sold for 25% lower, at $127 per 1000 fbm. Aspen waferboard (3/8 in. basis) sold for about $130 per 1000 sq. ft. in 1982.

Our analysis showed that from a unit wood volume, stud manufacturing utilizing purchased energy would be most economical. Although veneer manufacturing would bring 10-15% higher returns per unit volume of wood, the actual amount that can be utilized is at best only one-third of what can be used for studs. Waferboard products bring a 10-15% lower return than studs for the same volume of wood. Utilizing aboveground aspen tree biomass or only mill and logging residues for sale of energy is the least economically viable alternative. Product recovery and economic returns from spruce, pine, and fir are around 30% higher than those from aspen.

An integrated complex utilizing aspen for veneer stud, dimension lumber, and waferboard combined with an on-site energy conversion plant would offer a good compromise, with somewhat lower economic returns than a single product option but with nearly complete aspen utilization ensured.

Further details of this study are included in ENFOR Report P-207, *An integrated utilization of aspen for wood products and energy.*

Bill Ondro
Imre Bella

Grading of 2 X 4 production from aspen stands

Stand	Construction	Utility	Economy
Old	40%	44%	16%
Mature	60%	30%	10%
Young	29%	36%	35%

ENFOR studies at NoFRC

The national ENFOR (ENergy from the FORest) program comprises two subprograms: Biomass Conversion, which is concerned with the transformation of biomass into energy, fuels, and chemicals; and Biomass Production, which is concerned with forest-oriented subjects that relate to the supply of biomass. NoFRC has actively supported only the Biomass Production subprogram.

The Biomass Production program has four major goals: biomass availability, biomass harvesting, environmental impacts, and intensive silviculture. The present regional ENFOR program has the following objectives that relate to the national program:

- develop and test biomass prediction equations for regional tree species and lesser vegetation and demonstrate their integration with resource inventory programs,
- investigate the impact of biomass removal on site quality, nutrient status, silvicultural options, and long-term site productivity on selected sites in the prairie provinces,
- determine production and delivery costs of biomass under various operating conditions and provide a basis for evaluating the feasibility of using various forms of biomass for energy, and
- develop and operate a computerized biomass data bank and information retrieval system to provide for more effective use of information and technology transfer.

ENFOR projects are selected from among proposals submitted by private and public research organizations according to scientific and technical merit and in the light of overall program objectives and priorities. Projects are carried out primarily by contract with the private sector. During the first 5 years of the program 12 projects were initiated under the guidance of NoFRC, and four further projects are being undertaken during 1983-84.

Projects within the region have covered a wide range of topics: Biomass volume and yield tables for aspen; Line intersect sampling of forest fuels; Crop density and growth rates of woody plants; Tree biomass prediction equations for the prairies and NWT; Stand growth model for aspen; Computer mapping and demonstration of a biomass inventory system; Climate, biomass, and tree ring analysis; Climate and tree growth literature survey; Harvesting and chipping aspen; Nutrient relationships for aspen stands (P-205); and Integrated harvesting and processing for poplar wood products and energy. With the exception of P-205 all the projects have been completed, and reports are published or are shortly to be published. Project P-205 was started in 1981 and is scheduled for completion in 1984.

Two of the new projects are in the areas of integrated utilization for forest products and energy in Manitoba and green-volume specific gravity of tree species in the prairie provinces, and we are assisting the national program with completion of the Manitoba forest biomass inventory and sampling of noninventoried areas and nonsampled cover types in the prairie provinces and Northwest Territories.

John Powell

Biomass weight tables for the prairie region

The major commercial use of forests in Canada is for lumber and pulp production. All the nonstem components and the stem tops smaller than a specific diameter end up as harvesting residues in the forests. Such residues are a potential source of energy.

In Canada, Reed and Overend (1981) recently estimated that the unused forest harvesting residues amount to 102×10^6 t (ovendry), which is almost three times the current usable and marketable material produced. Besides this, an estimated 108×10^6 t (ovendry) of unused biomass is potentially available on productive forest lands. On a sustained yield basis, the available tree biomass in Canada is estimated to be 219×10^6 t (ovendry).

In the past, foresters were interested only in stem volume or its merchantable portion. But volume is not a suitable measure of nonstem tree components. For describing biomass of any kind, ovendry weight has become a universally accepted unit of measurement.

The first step in estimating forest stand biomass by component is the development of weight tables for different species in terms of easily measurable variables such as diameter at breast height (dbh) and total height. These relationships have now been developed for all major tree species of the prairie provinces (Singh 1982a).

Three different models using dbh and total height as predictor variables for estimating the ovendry biomass have shown good fit. For living tree aboveground biomass (without foliage), the R^2 values for the 10 tree species ranged from 0.96 to 0.99 for the best model. Using dbh alone, R^2 values also ranged from 0.96 to 0.99, although most species were near the lower end of this range.

Weight tables have been published (Singh 1982b) based on the model

$$W = a_0 + a_1 D + a_2 H + a_3 D^2 H + a_4 D^2 + a_5 D^3$$

where W is the ovendry biomass weight, D is the diameter at breast height, and H is the total tree height. The model parameters a_0, a_1, a_2, a_3, a_4, and a_5 were estimated as regression coefficients from the data collected.

The biomass equations for each tree species describe the relationships of dbh and total height with the biomass of various components such as merchantable stem, nonmerchantable stem, stump, big branches, and small branches without foliage. These predicting

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Aspen as an energy source — problems ahead?

Aspen, an abundant but little-used tree species in western Canada, has good potential as an alternative energy source. Studies to determine biomass production in aspen stands on different sites and the distribution by component (stem wood, bark, branches, etc.) provide background information to help plan viable harvesting operations.

Intensive harvesting for energy use would likely mean the removal of all the aboveground woody plant components. If done on a relatively short rotation to maximize production, it could lead to soil impoverishment by removing plant nutrients faster than they are replaced. This could significantly reduce forest productivity in the future. In order to prevent this, it might be necessary to take precautions such as restricting harvesting to the winter season and using only stem wood and branches.

A 3-year study to determine the total amount of biomass and nutrients in different components of aspen stands in Alberta is currently under way. This information is a first step in determining the ecological consequences of harvesting aspen for energy. At a later date it will be necessary to study the rate at which soil nutrients become available for use by the trees.

Ivor Edwards

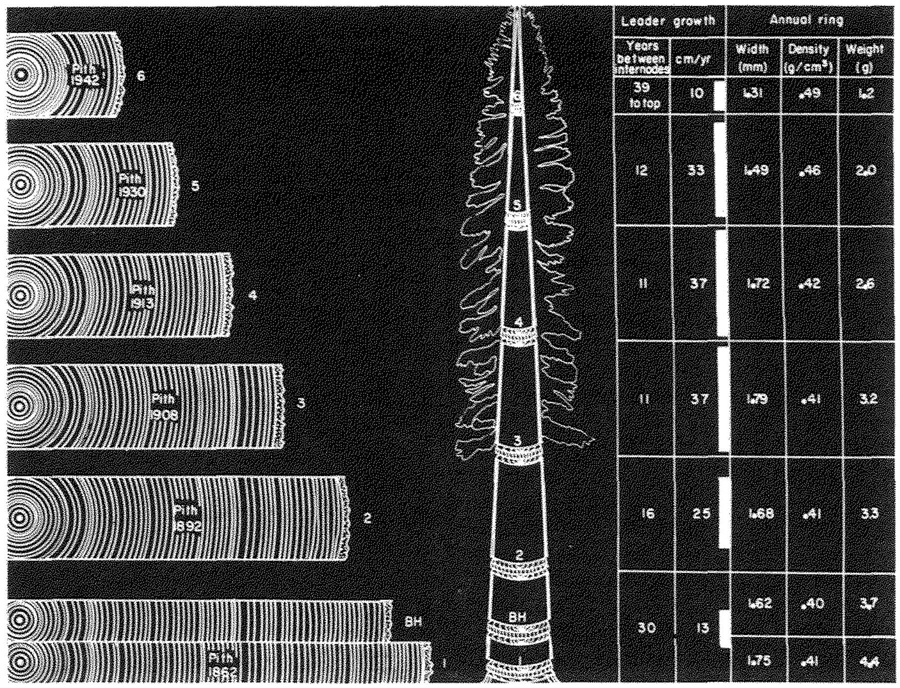
Determination of annual stem-wood biomass productivity

Various growth characteristics such as rate of growth by volume, weight, or ring density, from pith to bark or from the base to the top of the tree, can be obtained through tree-ring analysis. Ring parameters such as width, density, volume, and weight can then be used to establish annual and cumulative growth trends, including biomass, for specific locations.

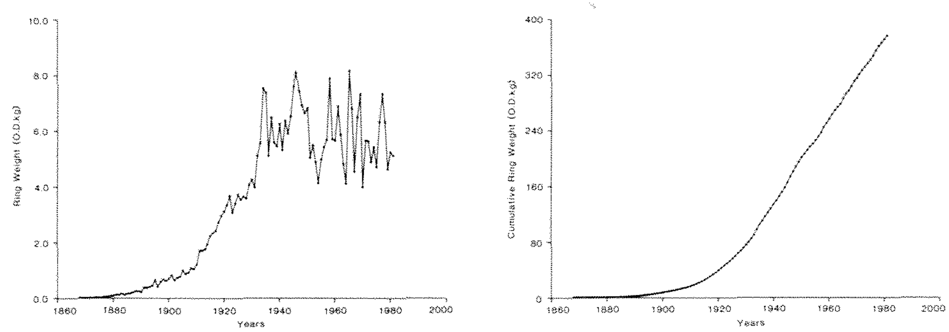
A study is in progress to estimate annual forest biomass production in relationship to climate. Stem sections were collected from four white spruce trees at 16 locations along two south-to-north transects near 100° and 115° W longitude from the southern limit of the boreal forest to the open subarctic forest. Seven cross-sectional disks were cut from each tree at levels indicated on the illustration, and thin radial cross sections of each disk were prepared. Radiographs of each section were scanned on a computerized densitometer over incremental distances of 0.1 mm, which converts light transmission of the wood-sample image into detailed ring width and ring density chronologies for earlywood and latewood components of annual rings.

The volume and weight of the entire annual increments in a stand can be obtained by processing the data for the four intensively sampled trees at each location. The weight of the entire annual increment depends on (a) its distance from the pith at the base of the stem, (b) its ring width along the stem (taper), (c) its average ring density, and (d) its distance up the stem to the tip of the leader for that year's growth.

The accompanying figure illustrates information (including ring weight based on a 1-cm thick disk) collected for a 120-year-old white spruce tree sampled at Suwannee River, Manitoba. The two graphs show stem-wood biomass as a function of age on an annual and cumulative basis for the same tree.



Tree-ring statistics for a 120-year-old white spruce.



Yearly stem-wood biomass as a function of age (left) and cumulative stem-wood biomass as a function of age (right) for a 120-year-old white spruce.

This method of computerized x-ray densitometry thus can be used to estimate stem-wood biomass productivity as a function of time (years), and it is hoped that it can also be related to climate and climatic trends. Furthermore, comparison of breast height disks with whole tree statistics from other locations should prove valuable, because most forest stand cruising and inventory work is based on breast height data.

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Biomass

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equations are additive, so coefficients can be added to obtain equally valid equations for a combination of components such as total stem biomass and total branch and foliage biomass.

Because the nonmerchantable stem and the nonstem tree components form the bulk of residues left in the forest, weight tables estimating these components are necessary if these materials are to be used as an alternative energy source. Tables for the three prairie provinces and the NWT have been developed from the prediction equations established for each tree species (Singh 1982b, 1983).

Related work at NoFRC includes a pilot project for demonstrating the conversion of a conventional forest inventory to a biomass inventory over an area, e.g., a township. The direct relationship between volume and weight is also being studied, and methods are being developed by which volume inventory can be converted to biomass information. Similarly, the variations within and between the specific gravities of the major species of the prairie region are being determined to provide a direct method of converting tree volumes to biomass weights.

Teja Singh

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Harvesting aspen for energy may be economic

The cost of harvesting is one of the main obstacles to increased utilization of the abundant aspen resource in Alberta. New methods of harvesting and the use of aspen biomass as an energy source may give the needed boost to aspen utilization.

The high incidence and unpredictability of decay in mature aspen stands hinders traditional utilization of this species for wood products. Harvesting aspen for energy alleviates this problem. To establish the costs related to such utilization, a contract study was carried out in 1981 in west-central Alberta that compared the productivity and costs of harvesting two aspen stands using two harvesting methods. The younger stand was 37 years old, covered 3.8 ha, and had 3700 stems/ha and an average diameter at breast height (dbh) of 18 cm; the older stand was 58 years old, covered 4.9 ha, and had 832 stems/ha and an average dbh of 30 cm. One-half of each stand was harvested with the Dika side cutter, and the other half was harvested with a chain saw.

The Dika side cutter is basically a land-clearing implement designed to operate as a blade on a crawler tractor. It was used with a low-power (175 kW) Caterpillar D8H tractor with a speed of 5-6 km/h and was effective for felling trees up to about 25 cm dbh. For larger trees, a Caterpillar D8K tractor (224 kW) was powerful enough at a constant speed to shear off even the largest trees. The cutter mounted on the smaller tractor harvested the younger stand 12 to 13 times faster than a chain saw. In the older stand, the same cutter mounted on the more-powerful D8K tractor had a harvest rate 14 to 15 times that of a chain saw.

The costs of harvesting, skidding, and piling in the younger stands were $28.60/t (ovendry) using the side cutter and $39.30/t (ovendry) for the chain saw, a 37% difference. In the older stands, the costs of chain saw harvesting were 34% higher, $9.33/t vs. $12.50/t (ovendry). The costs of trucking from younger and older stands, adjusted for distance, were $11.75/t and $7.15/t (ovendry), respectively.

Chipping by a Nicholson 22 CTU chipper cost $12.90/t (ovendry). Tree size was most important in determining unit cost for all phases of the harvesting operation.

Analysis of the biomass recovery of complete tree (above ground) showed that nearly 90% of the aspen biomass was recovered in both the younger and older stands. This means there was a substantial improvement in fiber recovery over that of current shortwood and tree-length harvesting systems.

In the older stands, closer analysis and streamlining of the field operation after a series of field trials resulted in reduction of harvesting costs to $22.81/t (ovendry), of which $0.60 went for felling, $6.65 for forwarding and loading, $7.16 for trucking and unloading, and $8.40 for chipping. Skidding was done by the forwarder.

Graded aspen logs showing rot.

If aspen biomass is to be used for gasification, further costs are added, e.g., gasification process, cleaning, and compression costs. The total capital cost of a 64 GJ/hr higher heating value (HHV) wet gas fluidized bed gasifier of the B.C. Research type is $1.4 million according to Alberta Industrial Developments Ltd. 1980. The annual operating cost not including fuel is estimated to be $100,000. The life-cycle costs of this unit depreciated over 5 years to a 10% residual value at a 15% discount rate result in an energy equivalent value of wood gas of $2.44/GJ. The Alberta border price for natural gas is $2.63/GJ (August 1983); therefore, on an energy equivalent basis, wood gas is competitive with natural gas. Based on the September 1981 Ottawa-Alberta energy-pricing and revenue-sharing agreement, which established a 5-year pricing regime whereby the price of natural gas will rise every 6 months by $0.2330/GJ, after mid-1983 wood gas derived from aspen chips became cheaper than natural gas.

In addition to being an economically viable alternative, utilization of aspen as a source of fuel to generate low kilojoule gas may have other social and economic benefits. For example, if harvesting operations reduced site preparation costs for current Alberta Forest Service afforestation programs by $150/ha, this saving could be added to the value of the aspen chips. Based on 84.5 t (ovendry) of available material per ha, this cost saving amounts to $1.78/t (ovendry).

Further details of this study are available in ENFOR Report P-163, *Costs of harvesting aspen stands for energy production.*

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