

1983

THE NORTHERN FOREST RESEARCH CENTRE

Contributions to wise management
of forest lands.

by

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".....there will be a shortfall
of near forty percent in the
abilities of the Canadian
forestry sector to supply
domestic and foreign markets
by the year 2000."

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Introduction

The boreal forest knows no administrative boundary in its stretch from the interior of British Columbia, the Yukon Territory east to the Maritimes and Newfoundland. That forest is the dominant Canadian, and global, vegetative landmark. Plant communities within its border exhibit great diversity, but also retain an individual commonality throughout the vast expanse. Within the region served by the Northern Forest Research Centre, the greatest percent of wood harvest by far originates from the boreal forest.

The Northern Forest Research Centre, located in Edmonton, is a federally supported facility, within the Department of the Environment. Within that department, it constitutes one research component of the Canadian Forestry Service. Others are located in British Columbia, Ontario, Quebec, New Brunswick, and Newfoundland. The Northern Forest Research Centre provides forested land management research, development, and demonstration services within a region comprised of the provinces of Alberta, Saskatchewan, Manitoba, and the Northwest Territories.

It is fair to say the Northern Forest Research Centre, and its predecessor(s), is the principal single source of information relating to the vegetative and to a large degree, soils characteristics of forested lands within this region, and the responses of those forests to manipulation. With respect to protection of those forests, the same holds; behaviour of fire, distribution and impact of insects, fungi, and air pollutants. The Northern Forest Research Centre is the paramount regional agency gathering economic and employment data vis-à-vis the forestry sector. Few studies are so narrow results have application in

only a single region or to a single agency. In so stating, however, the NoFRC recognizes a careful distinction must be made between that type of information and its use within systems of land management. The NoFRC makes important contributions to components of those systems, but their development in total and their application is the responsibility of the agencies themselves, which they handle with skill. In addition, it is well recognized major research contributions have been made by other agencies such as universities, and provincial forest services.

Many of the forested land management groups utilizing information from the NoFRC and, in many instances, active partners in NoFRC research and demonstration studies, are not aware of the full extent of its overall contributions to forested land management at the national and/or regional level.

The purpose of this report is to provide a holistic overview of the work undertaken by the NoFRC and the contribution to wise management of regional forested lands. This, against a background of expected wood shortages and provincial/federal strategies aimed at their resolution. In addition, to focus upon the intent of the NoFRC to dedicate its facilities and skills towards assisting regional management agencies reach their expanded productivity goals.

The forest industry in Canada, and this region specifically, depends currently upon naturally established stands for commercial harvest. Within the lifetime of children entering schools today, the forest industry must be harvesting from forests having received considerable stand husbandry, if not man-established. Such is the challenge and its urgency.

1. The Forest Resource

Forests dominate the landscape of Canada. Commerce arising from use of those forests are a major influence in shaping our economic, social, and political lives. The extent of forest cover in Canada is summarized below, together with that of the productive forest land, and estimated wood volumes by region.

Forest Lands in Canada

Regions	Total area sq. km	Area of forested lands sq. km	Area of productive forested lands sq. km	Wood volumes in millions cu. m
Atlantic	502	395	179	1232
Quebec	1357	940	849	4929
Ontario	891	807	426	3599
Alberta, Saskatchewan, Manitoba	1762	875	462	2863
British Columbia	931	633	515	9731

Source 7

The forest resources of Canada have been primary generators of income and employment throughout our history. Their paramount role in the social and economic fabric of Canada is demonstrated by these few statistics (1980-81):

- 310,000 employed directly, nearly one million indirectly or one job in 10 in all of Canada.
- 22 billion plus dollars in value of shipments or 14 percent of all manufactured goods.
- exports of 12.8 billion dollars with a total net earnings of foreign exchange of 11.8 billion dollars.

- The next nearest industry was the iron, steel and nonferrous metals which provided a net foreign exchange credit of 6.2 billion dollars.
- In transportation, forest products account directly for one-eighth of total railway carloadings.
- In 1981 the industry accounted for 20 percent of total new investments in Canada.
- industry and their employees paid over 3 billion dollars to provincial (57%) and federal (43%) treasuries.

Further evidence is provided by the data within the tables below.

Regional Distribution of Total Forestry Sector
Employment and Sales Values (Statscan 1980)

Regions	Employment in Thousands	Sales Values in Billions
Atlantic	26	1.9
Quebec	82	5.8
Ontario	79	5.7
Alberta, Saskatchewan, Manitoba	19	1.4
British Columbia	98	7.4

Manufacturing Activity--Woods Industry 1979 (Statscan)

Regions	No. of p/y	Value of Shipment in Millions \$
Atlantic	5,880	351
Quebec	24,087	1,609
Ontario	19,283	1,320
Alberta, Saskatchewan, Manitoba	8,736	679
British Columbia	44,850	4,841

The combined wood volume resources within Alberta, Saskatchewan and Manitoba are somewhat less than Ontario. They are more than double that of the Atlantic provinces. The regional level of manufacturing values exceeds that of the Atlantic region by a considerable amount, but is somewhat less than that region when total forestry sector values are compared. Quebec, Ontario, and particularly British Columbia dominate the forestry sector in Canada. Nevertheless, while a forestry image is not conjured up in the minds of many of its residents, the forestry sector constitutes a significant physical and economic factor in lives of the citizens of the so-called prairie provinces. Within this region the forests of Alberta tend to dominate in both harvested volumes and economic returns. The total extent of this region's forest inventory, current level of development, and potential expansion cause it to be an important "player" in national programming.

2. The Future

Serious constraints threaten the Canadian timber supply and the forest industry growth prospects. This translates into a forecasted shortfall of 40-50 percent in Canada's ability to capitalize on the expanded domestic and global market opportunities by the year 2000.

That is the viewpoint held by the Canadian Council of Resource and Environment Ministers, the Canadian Forestry Advisory Council, industry, universities, and professional foresters.

The (Federal) Forestry Sector Strategy for Canada, a document published in 1981 is of historic importance. It is a document having immediate and long-term social and economic implications, for it essentially addresses those two subjects. It states in essence that the industries in total constitute a vital sector of the Canadian economy. There is a grave danger that sector will be unable to maintain its present role in the national and international economy by the year 2000. That situation will arise because, from the best forecasts that can be made, there will be a large shortfall in available timber to meet anticipated market demands and opportunities.

In anticipation of that timber shortfall, and with good reason to believe it can be avoided by acceleration of forest renewal programs, among others, the federal government will actively seek joint funding agreements with provincial governments and industry. Those agencies are in agreement a stronger effort is needed towards more intensive forest management. Negotiations towards creation of those agreements are currently in progress. The Canadian Forestry Service and its regional Centres are designated to be the "federal windows" in the

drafting and negotiating of those agreements.

A 40 percent increase in sustainable timber harvest is the goal and that goal is considered attainable. It will come about by an accelerated forest renewal program, utilization programs, and improved protection from fire and forest pests. Of these three priority areas, forest renewal or intensive forest management is considered paramount. The economic and social impact of this major thrust is estimated to provide an increase in employment of 75,000-100,000 jobs, an additional 12 billion dollars in foreign exchange earnings, and a whole range of spinoffs throughout the economy.

The provinces own most of Canada's productive forest land and carry the responsibility for seeing that it is managed to an acceptable level. Their jurisdiction, including the right to allocate or sell timber, is accepted by the federal government without qualification.

Both domestic and export markets for wood products are cyclic, with subsequent impact on government and industry revenues and on employment. This cyclic phenomenon underlines the need for a long term approach to forest management. Unlike other industry sectors, the current year's raw material supply cannot be managed on a year to year basis, nor can that management be speeded up or retarded with the business cycle. Harvestable forest crops currently require anywhere from 60 to 160 years of growth, depending upon end product and geographic location. Regardless of the economic cycles, those forests must be managed on an even and continuing basis and in a professional manner. That requirement now appears to be nearer fulfillment than at any time in the past.

3. Some History

By the late 1800's, perceptive observers in both the older provinces, and within the Government of Canada, had sadly observed the devastation to the prime forests from wasteful and destructive forest harvesting practises and uncontrolled fires. The Dominion Government, from Prime Ministers down, had hopes such practises would not occur with the forests of the new lands to the west. They must be given full marks for high and noble intentions. Many years were to pass, however, before intensive forest management was recognized as an achievable goal. Many more years passed before the first initial practise of such management.

The history of forest management in the provinces of Manitoba, Saskatchewan, and Alberta differs from that of any other region of Canada. Within these provinces, control of natural resources, including forested lands, was not passed to them from the federal government until 1930. That event followed decades of intensive lobbying. The passage was officially enacted by the Natural Resources Transfer Bill.

The Dominion Land Act was enacted in 1872. It consisted of 108 separate clauses; among them, establishment of the Dominion Lands Office. That office outlined a system of surveys covering lands in Manitoba, and the Northwest Territories (Saskatchewan and Alberta specifically). It specified how those lands were to be disposed and made specific reference to timber sales and establishment of reserve. Over 5,000 square miles were turned over to a forestry section for control and management.

Early annual reports of the Department of Interior, in the late 1890's, record the establishment and concerns of a Forestry Branch.

Those concerns were directed at harvesting practises and lack of sympathy for good forest husbandry within the then waves of people emigrating into those virgin lands.

For nearly 62 years after Manitoba reached provincial status (1870) and nearly 27 years after ^{Alberta}~~Manitoba~~ and Saskatchewan were established as provinces (1905), the Dominion Government controlled and managed their forested lands. Within that government, the Dominion Forestry Branch set guidelines and regulated activities within stretch of forest extending from the western border of Ontario to the forested eastern slopes of the Rocky Mountains.

Of particular concern was the high incidence of forest fires, principally man-caused. The extension throughout the west of new railroad lines, development of both coal and other mining complexes were associated in those early days with a significant increase of forest fires. In addition, many of the settlers moving into the southern fringes of the boreal forest to carve out homesteads, considered the forest as an enemy and fire as an important weapon.

In 1903 the Superintendent of the Forestry Branch was able to proudly describe establishment (summer only) of a fire ranger service-- 22 in total; four in Alberta, one in Saskatchewan, and seven in Manitoba. Eight rangers were assigned to the railroad belt, then part of federal lands adjoining the railroads pushing through the mountain passes into British Columbia. By 1904 the fire ranger staff had increased in total to 40, with 12 assigned to protect the forests on the eastern slopes of the Rocky Mountains.

The first Forestry Branch Bulletin (#1) was published in 1910, titled Tree Planting on the Prairies of Manitoba, Saskatchewan, and Alberta. "This bulletin has been written with the idea of affording practical information to the settlers on the western prairies.....". By 1908 national forestry statistics were being compiled, including exports and imports, as well as technical bulletins on a wide range of forestry subjects from quality of wood to industrial processes.

The succeeding years saw extensive surveys conducted in commercial forest lands, silvicultural reports compiled, and recommendations relative to good forest management. Mode of travel into the thirties was by foot, horseback, boat and canoe, railroad and auto, where facilities, and few at the best, existed.

The annual Forestry Branch Report for the year ending 1921 records, "During the season of 1920 the Air Board of Canada inaugurated an airplane patrol over certain forest areas in charge of the Forestry Branch. Two patrols were established, one in the Alberta inspectorate and the other in the B.C. inspectorate. In both cases, however, it was not possible to begin patrols until the fire hazard season was virtually over. The Alberta station was at Morley.....".

Resources Transfer

Report of the Forestry Branch in 1930 includes this statement by the Director, E. H. Findlayson, "In the year under review agreements were signed with the western provinces for return of the natural resources, including the forests. This action will relieve the Forest Service of its former administrative function with regard to the protection and management of forested lands. The change will enable it to concentrate on investigations, research, and experiments.....".

".....avail itself of additional opportunities which are presented for investigation into basic forest protection problems for silvicultural researches into the rates and conditions of growth of Canadian tree species, for forest production research looking to closer utilization of Canadian raw materials and for the more intensive prosecution of the national inventory of forest resources now actively under way". Thus ended a Federal stewardship which history has recorded, had many noble accomplishments but many unmet goals.

Most employees chose to transfer to the various provincial agencies, where they brought their many years of experience to assist the provinces establish their own agencies. Others remained with the Dominion and served at experimental stations and in National Parks. Others left and entered the private sector.

The intervening years to the present have witnessed many changes in structure of the former Dominion Forestry Branch, and of the provincial government agencies established to take over the management duties. It can be stated relations between the two agencies have been co-operative and productive.

4. Federal Programs in Aid to Forest Industry and Forest Management

The federal government has played a supportive role within the forestry sector for many years, subsequent to return of the forest resources to the provinces.

Composite federal/provincial forestry agreements were in place during the years 1951-67. Under those agreements the federal government shared in the cost of inventories, reforestation, fire protection, access roads and stand improvement, spraying program for spruce budworm and employment stimulation totalled 225 million, in 1981 dollars.

Forest sector federal funding conducted under the Agricultural and Rural Development Act (ARDA), Fund for Rural Economic Development Act (FRED) and the Department of Regional Economic Expansion (DREE) during the years 1967-1974 totalled 526 million dollars. Federal commitments to aid pulp and paper mill modernization, with provinces, will total 279 million dollars by time terminated in 1983.

The federal government expends the major share in forest research funding; 44 million dollars plus 6 million to Forintek and the Forest Engineering Institute of Canada (1981).

5. The Canadian Forestry Service: Objectives and Goals

The Canadian Forestry Service is a national organization, with its headquarters and senior management located in Ottawa. It has research centres located in each of the regions and cities across Canada; Newfoundland, St. John's; Maritimes, Fredericton; Quebec, Quebec City; Ontario, Sault Ste. Marie; mid Canada, i.e. Manitoba, Saskatchewan, and Alberta, Edmonton, and British Columbia, Victoria. A national institute is located in Ontario, Petawawa.

The objectives of the Canadian Forestry Service have not altered from those stated by Director Findlayson in 1930, i.e. "..... undertake investigations, research, experiments into basic forest protection problems, silvicultural research into rates and conditions of growth of Canadian tree species.....and intensive prosecution of the national inventory of forest resources. In summary, provide knowledge to aid in the wise management of Canada's forested lands".

The Canadian Forestry Service, since its inception as a research and development organization in 1931, has striven to develop and maintain a high level of research capability in the management of forested lands. Like most organizations with a relatively long history, i.e. vigour and effectiveness in its different program areas have tended to "wax and wane" over time. In addition, the need to accommodate administrative and economic reorganizations has resulted in benefits, and unfortunately disbenefits as well. Critical research capabilities in areas now deemed of essential national need have been greatly weakened and, in important instances, lost to the Government of Canada. Nevertheless it has, with the exceptions noted, been able

to maintain a degree of excellence which is the requisite of a productive scientific and technical organization. It remains in place as the paramount integrated and unified forested land research group in Canada. The CFS programs are "interwoven" into the fabric of both regional and national forested land management objectives.

Goals of the Canadian Forestry Service fall within two broad categories; those directed towards national needs, and those directed to needs of regional land managers.

The federal government, through its Acts, and parliamentary decisions, has enormous influence on the economic health and vigour within the forestry sector. Centres, such as NoFRC provide relevant and up-to-date information relating to regional activities. Such information on economics and forest renewal, aids in the formulation of constructive federal forest policy decisions, and in summarized form are made available to the forestry community as national statistics.

Other national goals contribute towards the establishment and maintenance of nation-wide communication and planning between the CFS, other federal agencies, provincial, industrial, university managers and researchers; examples, Canadian Committee on Forest Fire Protection, Canadian Forest Inventory Committee, Long Range Transport of Air Pollutants, The Pest Control Forum. In addition, national goals relate to co-ordination of regional CFS programs which impact on national forestry matters. For example, the Forest Insect and Disease Survey, Energy From the Forest.

Regional goals are largely determined by information needs of the regional management agencies within the governments of Alberta,

Saskatchewan, and Manitoba, the Northwest Territories, and National Parks. Few of regional programs could be undertaken without the co-operative, and frequently major logistic and financial support of these client agencies.

Forest management agencies within this region place high priority on the production of quality regeneration stock, spacing and early stand density information, establishment of genetically improved seed orchards, stand development data, site classification systems. In forest protection emphasis is upon improved fire protection technology, maintenance of up-to-date surveys and impact data of major forest pests, establishment of air pollution impact surveillance systems in vicinities of industrial plants.

The NoFRC has research programs in subjects which are not directly related to the resolution of timber management problems. Specifically, these are mountain watershed research, land classification within national parks and sensitivity classification of northern (Arctic) landscapes. The studies relating to air pollution impact on vegetation and soils, while forming part of the NoFRC protection research group, also make substantial contributions to the general area of environment protection. These programs receive major management agency support. The NoFRC support will be maintained.

6. Northern Forest Research Centre Programs of First Priority

Certain programs underway in the Canadian Forestry Service across Canada have been identified in the recently published federal forest policy, as being of first order priority and deserving of significant increase in emphasis.

- Negotiation of Federal/Provincial agreements to aid provinces in their move into intensive forest management.
- Compilation of forestry statistics relating to forest renewal, inventory, and silviculture.
- The compilation of economic statistics as related to the regional and national performance within the forestry sector.
- Information, dispersal and distribution, new and old, with improved compilation and communication.

In the pages following this section, past and present research and development programs undertaken by the Northern Forest Research Centre will be described in summary form. We believe that program has been productive and contributed in important ways to effective management of regional forested lands. It will also provide readers with a more holistic understanding and appreciation of that program.

Federal and Provincial Agreements

The Northern Forest Research Centre has mobilized in situ resources, and hired additional with economic training, to implement that program. Both the federal and provincial negotiations will be guided in part, and encouraged by successes of the earlier agreements in place from 1951 to 1967. First step in the process is negotiation of the umbrella Memorandum of Agreement (MOU). These are expected to be in place before end of the current year.

Integrated National Forest Resource Data (FORSTAT)

Federal and provincial discussions at all levels from the ministerial Canadian Council of Resource Ministers (CCRM) to Northern Forest Research Centre staff and regional agency managers agree there is a critical, immediate need for accurate forestry sector data. Specific to forest renewal is data relating to total inventory and its growth rate, annual harvest, losses from natural hazards, extent of forest renewal activities.

The Canadian Forestry Service has, for many years, collected forestry related data and compiled that data into national statistics. Those statistics provided general information on the forestry activities in any one year. That data has been found inadequate for both provincial and federal needs. With strong support from both levels of government, and in agreement with Statistics Canada, the Canadian Forestry Service initiated, in the late 1970's, a more intensive collection of forestry resource data. This was facilitated by establishment of a Forestry Statistics and Systems Branch headquartered in Ottawa, a province/industry user committee (Canadian Forest Inventory Committee) and representation from all regional CFC research centres, through the Canadian Forest Resource Data Program. Completion of the first report, published in 1982, represents an important step in federal/provincial plans to intensify Canada's forest renewal program. Information from that report has been used in compilation of tables within this report.

The extent, quality and distribution of the Canadian wood supply is illustrated and summarized in map and table form and are generated by a computer based system. The basic data are summarized by "cells" or areas having a target size of 100 km². Across Canada, about

40,000 cells are used to store data. Included in the first report are wood supply, national and provincial totals; extent and quality; forest land; stocked, productive non-reserved forest land; volume distribution; non-stocked, productive, non-reserved forest land.

In addition, a biennial national review of silviculture is to be part of that program together with other important summaries of components of intensive forest management. The Northern Forest Research Centre has been assigned the task of providing that review as part of the FORSTAT program. The first report has been published. As in the inventory report, provincial and territorial governments supplied the data on their respective silvicultural (stand treatment) statistics. That report contains a great amount of silvicultural data. It confirms that the levels of site preparation, planting, and seeding for the years 1975-80 are inadequate for the degree of intensive forest management necessary to reach the stated provincial/federal goals of the year 2000. Current level of stand tending is summarized below.

Summary of Silvicultural Activity in Canada

Management Activity at National Level	National 5-year Average
Total area harvested	759,438 ha
Total area of site preparation following harvest	165,916 ha
Percentage of site preparation over harvest	21 percent
Percentage of planting following harvest	17 percent
Percentage of direct seeding following harvest	5 percent
Area of stand tending as a percentage of productive forest land	0.03 percent

Economic statistics and employment

An up-to-date and extensive information base consisting of data relating to economic capacity performance and new investment within the forestry sector is essential to meeting the provincial/federal goals of increased productivity. Such a base, accessible in full to all agencies, is being compiled at Northern Forest Research Centre, relating to regional economic and employment statistics. The NoFRC maintains a continuing program for this purpose. It is a program encouraged and supported by all the provincial governments, industry, and Statistics Canada.

Major forest industry surveys were published for Alberta, Manitoba and Saskatchewan in 1972. More comprehensive surveys were completed in 1982 and are in preparation for publication at this date. The Northwest Territories were included in the 1982 survey. These surveys, involved detailed questionnaires and personal interviews with industry representatives. They provided statistical descriptions of the major economic and employment impacts and vigour of the forestry sector within this region of Canada. Many additional information spin-offs have been released in the form of directories, statistical fact sheets, provincial forestry profiles and detailed technical reports.

Data within these information publications aid all agencies in their planning, provide local regional, national and international perspectives to the regional forestry sector.

Information and communication

Communication from, and into the Northern Forest Research Centre probably consumes a larger part of staff time than any other single function; publication and dissemination in the form of the printed word; involvement in outside and NoFRC sponsored symposia, hosting of national and regional annual meetings of technical and scientific associations, participation in regional, national, and international meetings, and participation in a plethora of committees, chaired by, participated in, or monitored by NoFRC staff.

From the early 1970's to time of this writing the NoFRC has published close to 1500 titles in scientific and technical journals, information reports and notes. Most are directed towards technical audiences, but a substantial number are also written to inform the public. Over 100,000 individual items of printed material are distributed annually. Many more thousands are reprinted and distributed by client agencies.

Technical and scientific symposia and conferences of regional, national, and international interest are hosted by, or in co-operation with other agencies. These range in subject matter from sulfur dioxide impact on the environment, fire ecology in resource management, to the annual meeting of the Intermountain Nurserymen's Association.

The NoFRC staff, in varying degrees, are deeply involved in committee work covering the whole spectrum of forested land management concerns. Composition of those committees are inter- and intra-discipline agency, industry, and government; are regional, national and international. The purpose of the committees all include one or more of these objectives: to negotiate, co-ordinate, inform, and/or activate. Shortcomings of

committees are well known, but until a better forum for reaching those objectives is devised, committees will remain an integral part of information and decision-making processes.

Specifically, staff at NoFRC are involved with the business of nearly 100 permanent committees having interest in forest and environmental land management. They chair or otherwise participate in regional committees such as: Canada/Alberta, Canada/Saskatchewan, and Canada/Manitoba Research Program Advisory Committees. Associate Committee on Hydrology; Regional Silviculture Committee; Western Committee for Crop Pests, etc. National committees such as National Research Council Committee on Hydrology; Long Range Transport of Air Pollutants; Beaufort Sea Project Team; Canada Committee on Ecological Land Classification; Climate Advisory Committee; Canadian Forest Pest Control Forum; Canadian Committee on Fire Control.

A major staff function, difficult to adequately record, involves personal communications with management agency personnel, and the public made by individuals. These are a continuing activity at both daily, and less frequent intervals. They take place at the person to person level in the laboratory and in the field, by telephone and the mails. These activities, in total, constitute an important part of the NoFRC communication program.

Extension services are an integral part of all research staff functions, i.e. via mail, telephone, personal actions. Nevertheless the NoFRC recognizes this function as an identifiable program. Professional foresters and support staff are located in Winnipeg and Prince Albert. Their role is to ensure the NoFRC research, demonstrations, services and

facilities are made available to those provincial agencies. In addition, they represent the NoFRC and assist in the implementation of regional programs. The size of the region presents this Centre with special communication problems. Sub-offices help to overcome them.

7. Forest Renewal: Northern Forest Research Centre Contributions, Past and Present

The Northern Forest Research Centre programs reflect direction and support from regional management agencies and guidance by federal forest policy stated within the Forest Sector Strategy for Canada paper of September 30, 1981.

In the area of forest renewal, research emphasis is on improvement in the quality of seed via superior quality, and survivability of nursery grown seedlings, on development of site classification systems and cost effective site preparation, determining of natural mortality factors so allowance can be made in planting densities, efficient and effective spacing of planted and naturally established seedlings, cost-effectiveness of thinning and fertilization, development of superior strains of tree species, development of effective models for purposes of accurately estimating stand growth and yield characteristics.

It must be appreciated this report is not a complete historical nor current account of Canadian Forestry Service, i.e. NoFRC regional contributions. Rather it comprises an effort to provide an overview of past, present, and future research and development programs. It focuses on those types of programs which are particularly relevant to intensive forest management goals.

Forest land classification

Forest renewal operations by all management agencies are guided by carefully determined plans. Reforestation must be approached in a systematic manner, and be guided by site classification systems based on sound ecological fact and measurement. This allows for matching productivity goals with effective site treatment and planting and/or seeding practises. Otherwise expensive and long-term site improvement programs can be delayed or negated, with consequent reduction in future wood supply.

The productivity of forested land is determined largely by: characteristics of its soil, i.e. nutrient, texture, organic matter, temperature, moisture; physical characteristics of the site, i.e. slope, aspect, drainage; and the local climate, i.e. temperature, precipitation, and wind. Managers require knowledge of these land characteristics. Site classification descriptions are in place and utilized throughout the region. Past research by the Northern Forest Research Centre has contributed to many of those classifications.

A major co-operative program in site development and classification is underway in Alberta. That study was initiated with provincial government operational funding in 1976. Its purpose is to classify provincial forested lands utilizing a classification system developed by Dr. Krajina University of British Columbia, and currently being put into place throughout B.C. The NoFRC role has been to adapt and modify that system for application to forested lands in Alberta, and undertake the first level of classification, a zoning at 1:1 mm. That has been completed. A joint NoFRC/Alberta pilot study is now underway to apply

that site information at an expanded level within a specified forested area comprising 4-6 million hectares. One objective of that study is production of a field guide for use by operational foresters in government and industry. This will provide readily available information to assist managers in making correct decisions regarding types of site treatment following harvest to minimize erosion, improve drainage, increase regeneration chances and select appropriate tree species. Managers will be aided in their goals of optimizing the productive use of land under intensive forest management.

NoFRC involvement in this site classification program has resulted in the accumulation of a great amount of site characteristics production data. That data is now quantified and within a data bank. During the course of the program, NoFRC has endeavored to ensure data gathered in the Alberta program was compatible in as many of its parameters as possible, with classification systems in use in Saskatchewan and British Columbia. A goal is to assemble compatible site characteristics/productivity data from all western provinces into an expanded information bank. The geographic and political origin of the data is not essential and can be removed as a prerequisite to entry into the bank.

An information pool of such large proportions, containing compatible and randomly obtained data on site characteristics/productivity from such an extensive area of forested lands, will be of inestimable value to research foresters in all agencies, governments, industry and universities.

A new study at NoFRC has as its goal improved understanding of major peatland formations within this region. Specifically identify

their associated vegetation, peat chemistry and plant remnant composition, and age. Peatlends occupy nearly 20 percent of lands designated boreal forest. An improved understanding of those regions will aid forested land managers making decisions respecting possible uses.

Site preparation

During the 1950's and 60's the Northern Forest Research Centre supported strong programs directed towards researching the merits of different harvesting methods as they affected subsequent establishment of regeneration. Methods such as partial cutting, seed tree selection, types of thinning guided by diameter and crown cover, and clear-cut were assessed. Regeneration of the logged site were determined following natural and artificial seeding, bare-root planting, retention of cone bearing slash. Field trials were undertaken in Manitoba, Saskatchewan and Alberta to appraise the performance of various types of scarifying equipment on the many varieties of logged-over sites throughout the region and within all forest types.

A forest harvest experiment of considerable complexity was put into place by the Canadian Forestry Service in the years 1950 to 1953 in the lower foothills region of Alberta. The experiment was undertaken to determine effect on lodgepole pine regeneration following different cutting systems and site treatments within. Age of the stand was 85 years. Results from that experiment and others which followed had far reaching effects on forest management, particularly within the lodgepole pine timber areas of Alberta. The clearcut harvest method with subsequent scarification as a site improvement method was found vastly superior to all other methods of harvest and treatment. Only that method produced a satisfactory level of regeneration. The area was given special status by the province of Alberta and named the D. I. Crossley Experimental Forest to honour the originator of that classical experiment. It is now under the management of the forestry department of the University of Alberta.

Results from NoFRC experiments and field trials demonstrated the superiority of clear-cutting followed by carefully prescribed scarification as most conducive and cost-effective for subsequent site regeneration. In many instances the regional management agencies and some industries were co-operators and provided logistics support. Results from those pioneering studies had a significant influence on the adaptation and subsequent complete acceptance of the clear-cut harvesting method as a good silvicultural practise.

Seedling production

Major expansions in nurseries and seedling production facilities have taken place over the past decade in all provinces. The Northern Forest Research Centre has an active program in developing and studying ways to produce high quality seedlings.

Seedlings stock for regenerating forested lands deficient in natural regeneration generally takes one of two forms, 2-3-year old bare-root or container seedlings. Historically bare-root stock dominated planting programs. Since the 1970's, however, planting of containerized seedlings has increased substantially and now dominates planting programs. Bare-root stock, however, remains important to all reforestation programs. The NoFRC has provided managers of regional bare-root nurseries with soil analyses and prescriptions to optimize nutrient regimes by fertilization, and soil texture with organic and inorganic additives. This is a continuing program.

Container seedling production began in the early part of the 1960's. By 1970 the variety of containers in use numbered close to a dozen. All regional commercial softwood species were being grown. Serious problems developed at all levels of the production process causing heavy losses, both in financial and seedling mortality terms. Planting schedules were disrupted.

Studies at NoFRC have aided nursery managers in many ways. Different containers were assessed in field trials as to their effect upon seedling root system development. Optimum media for seedling growth were determined, i.e. peat and/or mixtures with vermiculite. The physical and chemical characteristics of regionally available peat were analysed and specifications determined. Controls were determined for damaging fungi and preventative recommendations made. Optimum temperature, moisture

and photoperiod schedules for seed germination and for seedling growth were ascertained. Fertilizer regimes were described for enhanced overall growth and shoot/root ratios. Growth rates and hardening off characteristics were examined under different rearing schedules.

As a consequence of these studies and studies associated with bare-root stock, the NoFRC can justifiably claim to have made major contributions to nursery production within this region. Research studies continue and are currently focused upon optimizing fertilization regimes, improving vigour, and increasing seedling resistance to freezing temperatures. A major report, has been published as an aid to production of quality container stock.

Silvicultural treatment

Specialized equipment and machinery for use in silvicultural exists in a wide variety. New equipment is continually being developed and promoted for these special purposes. The Canadian Forestry Service, through a nationally organized committee, with provincial and industry membership, supports a program of equipment development, testing, field demonstrations and literature inventory. The Northern Forest Research Centre established a regional program in support.

An inventory of all planting machines, and scarification equipment in use and/or development is currently underway. That inventory will be made available to all forest managers. It will include costs, effectiveness, and other additions to the silvicultural equipment scene will be demonstrated at field trials throughout the regions.

The prescribed use of fire, or controlled burning, is a silvicultural post-logging site improvement option that has been studied at the NoFRC. The experimental burns associated with those studies were undertaken with co-operation and logistical input from the respective management agencies.

A controlled burn will usually remove small diameter slash, aerial parts of vegetation, surface moss, grasses, and litter. Varying quantities of the duff layer and deeper organic layers are also removed, depending upon intensity of the burn. Concomitantly varying amounts of mineral soil are exposed. Conditions for regenerating by planting, direct, or natural seeding are much improved.

Prescribed burn experiments have been completed for jack and lodgepole pine and black spruce. Prescriptions have been calculated regarding the intensity of burn to obtain a predetermined reduction of

debris and exposure of mineral soil. Undertaking site improvement by controlled burns is recognized as presenting risks which do not exist with scarification procedures. Nevertheless, information is available for use of prescribed fire as an option to scarification, as need arises.

The NoFRC has recently initiated a study to assess the effectiveness of various types of herbicides as an aid to regenerating logged sites. Their role as thinning agents of overdense stands is also being examined.

Survival of planted regeneration

Among all areas of research in forestry, information related to the natural establishment of forest stands is among the most difficult to obtain. At present we can only conjecture what the original stocking density was, the early mortality and its causes. Such information is vital to managers attempting to establish new forests following harvest or fire.

At the request of regional management agencies, the Northern Forest Research Centre, in 1971, undertook a major field monitoring program of established plantations throughout the region. The plantations varied in age from one to six years. With one notable exception, success ratio of the plantations, all bare-root, was low. Results of that survey focused the necessary attention on problems which had been largely ignored. Since that survey improvements have been made in quality of stock and planting techniques. In addition, container seedlings have become more common and plantation success in general, has improved.

A resurvey was undertaken in 1978 of the bare-root plantation judged successful in 1971. Plantation mortality during the 1971-1978 interval was determined, and varied from near zero to 12 percent. Plantations where fill-in operations had taken place maintained the highest overall survival. Among plantation problems identified in both surveys, competition, poor planting, poor root form, and adverse weather ranked highest. Conclusions of these surveys suggest major improvement can be incorporated in many of the regional bare-root planting programs.

Literally millions of container grown seedlings have been planted within this region, particularly over the past several years. Two survival and growth trials are underway of lodgepole pine and white

spruce container seedlings. One trial, initiated in 1971, constitutes a field evaluation program of several different types of containers, plus bare-root stock, with lodgepole pine and white spruce, planted within experimental plots extending from the mixedwood zone south along the foothills to the U.S. border. Planting tools were also evaluated. Initial results (5 year) indicated container reared seedlings were successful planted June, July, and August, whereas bare-root were successful only in June. The initial preplanting weight is very important as larger and heavier seedlings did better. The higher the shoot/root ratio, the better the performance. All containers gave satisfactory results but handling problems were not the same. Dibbles proved superior for planting in deep soils, whereas bars or spades were superior in shallow top soils. Frost heaving was reduced when container seedlings were set one cm below the surface and pressed in with soil. Minimizing soil disturbance reduced animal traffic and water channeling. Survival in all plantations was good to excellent. The plantations themselves were distributed within five forest districts of Alberta and one in the Northwest Territories.

A more recent NoFRC planting trial was commenced in 1981 in a co-operative study to determine the optimum size for container seedlings planted in Alberta. Plots are located in the mixedwood zone at three different elevations. Concurrently, another study will assess planting tools (planting bar and mattock) and planting depth effects on establishment of bare-root 2+0 lodgepole pine and 3+0 white spruce. Following one year, survival was good in all soil types, spring planting and fall, spruce (99%) somewhat ahead of pine (93%). Mortality factors

were flooding, frost heaving, and winter drying. No differences were detected between use of the planting bar and the mattock. Measurements were too soon after planting to determine growth trends. Survival and growth will be measured again three and five years following their outplanting.

A study to examine natural mortality within newly established lodgepole pine plantations was recently initiated by the NoFRC. The study involves scarified areas which were mainly self-seeded to lodgepole pine and were established between 1956 and 1975. Sixty thousand stems have been marked. This study represents a major long-term commitment by NoFRC. The study has not been in progress sufficiently long to supply reliable mortality figures. To date, mortality has been caused mainly by hares, gall rusts, and armellaria root rot.

Early stand density and spacing

Spacing levels and density of stems in young developing commercial stands have a major effect on the rate at which the stands will develop, and the volume and quality of trees at harvest. The need for information is critical. Managers initiating more intensive forest practises require such information to optimize early growth densities in naturally established stands and in plantations. The NoFRC has, over the years, and recently, maintained study programs to provide information. These studies have been in co-operation with and received support from the management agencies.

In southeastern Manitoba, jack pine and red pine have been extensively planted for nearly two decades. Study plantations of these two species were established in 1963 to determine optimum spacing densities. Four different spacing densities were compared. Recent assessments indicate jack pine should be planted at spacings between 2 and 2.5 m to optimize growth and tree form. Poor form and high growth occurred in jack pine at wide spacings. The red pine generally retains sufficiently good tree form at any spacing to satisfy particular management objectives. Stand productivity by basal area, volume, or biomass was highest at the closest spacing. However, faster growth at wide spacing suggests that the difference will be reduced or even eliminated by rotation age. The study concludes red pine should be favoured over jack pine on average sites in southeastern Manitoba.

Seedling spatial patterns were assessed in naturally stocked stands of 10-year old lodgepole pine and white spruce to estimate the minimum number of well dispersed trees required for complete site utilization at reference age of half-rotation (40-50 years). It was

concluded the minimum number of well dispersed trees per hectare required for lodgepole pine in the foothills zone was 575 stems. The minimum numbers of white spruce stems for sawlogs was 720 and 610 respectively for the foothills and mixedwood zones; 1100 and 900 stems for pulpwood in the foothills and mixed zones respectively.

These data have assisted in the determining stocking standards. Such figures are recognized to be of tentative value, however, as they do not account for subsequent mortality, as the stand ages. Nevertheless, they are of value in setting stocking standards and providing managers with a "fixed point" in stand development.

Lodgepole pine commonly forms overdense stands following wild fire. This condition leads to reduced tree growth, lower merchantable yield, and extended period of development. The effects of mechanically adjusting stem spacing within 25-year old stands, having different ages and on three different sites are under study. Densities were adjusted to five spacing levels; 500, 1000, 2000, 4000, and 8000 stems per hectare. Recent remeasurements have indicated some response trends, height growth was not significantly affected, as measured to date and at the specified spacing levels. Lodgepole pine appears to require some degree of crowding for maximum height growth. Wider spacing resulted in significantly greater diameter increment in some treatments up to 144 percent. Initially, stand basal area and volume increments, in addition to total stand basal area and volume, were highest at close spacing and declined at lower spacing. This may reverse with time.

These studies demonstrate spacing in young lodgepole pine stands had a substantial effect on stand growth and development. However, responses differed from those studies in comparable stands of younger

age (10 years), where responses between levels of spacing were more marked. This suggests the forest manager's planning flexibility declines as the age of the stand increases.

Tree improvement

Jack pine is an important timber species throughout the region. A genetic improvement research study was initiated by the Northern Forest Research Centre in 1967 with a completion date in the year 2001. The length of time required by studies such as these is an indicator of the degree of commitment. Mid-study results, however, indicate the potential value of this study. By 1979 and 1980 grafts of superior jack pine strains were provided to provincial governments for use by them in establishing experimental seed orchards. Within ten years plantings of selected superior grafts will be made available for establishment of operational genetically improved jack pine seed orchards. Early measurements show gains of 10-15 percent in height and increased mass of as much as 15 percent at 5 years of growth. An enormous beneficial impact on wood volumes will be realized in jack pine plantations throughout this region if such early gains are maintained.

Provenance trials of 12 Norway spruce populations from Canada, Europe, and USSR were established within this region in 1963. Measurements in 1970 and 1976 indicated first rank in survival and height growth occurred in the Russian strain followed by a strain from Ontario. Measurements will be continued.

A regional provenance trial of Scots pine from the USSR was initiated in 1960, from 3-year old seedlings reared at the Petawawa National Forestry Institute. Plots were established in Manitoba and Saskatchewan. To date, mean height of native jack pine equals the Scots pine mean. Evidence at this date is inconclusive as to any inherent superiority of the Scots pine vis-à-vis local jack pine.

Red pine provenance test plantations were established in Manitoba in 1958 with 5 populations originating in Ontario and one each from Manitoba, Michigan, Quebec, New Brunswick and Nova Scotia. When last measured, in 1973, superiority of outside provenances were judged not sufficient to justify any change from current practise of using local seed for planting of red pine in southeastern Manitoba. In addition, results do not support new seed source tests.

Stand treatment

The Northern Forest Research Centre is monitoring two operational thinning trials underway in dense naturally seeded jack and lodgepole pine. Thinning was by use of a large tractor drawn drum chopper. Thinnings were done in parallel strips near 3 m in width, with alternating strips of near 3 m in the jack pine. Somewhat less in the lodgepole pine. Both pine stands responded well with significantly improved diameter and height growth and establishment of dominance in trees on the strip margins. It is concluded this two-way strip thinning method has a potential usefulness in very dense and homogenous stands. Patchiness within a stand could result in serious understocking by this thinning technique.

Jack pine is a natural fire succession species and often reseeds itself at excessively high densities. A co-operative study is underway to assess effects of density on growth and stand development. Plots assessed in this analyses were established by management agencies as early as the 1920's. Later ones were established in the 1950's by the NoFRC. A recent analysis of measurements from those plots indicated generally increased diameters. Improved total yield, however, was only evident on good sites. It is concluded jack pine stands should be thinned when very young, preferably under 10 years of age, to maximize treatment. However, although costs are generally lower with early treatments these results also suggest that treatments can be delayed at least to age 20 without much reduction in tree growth and vigour. This allows time for the trees to express dominance and pass through the period between 10 and 20 years, when heavy losses may occur from a

variety of causes that could result in understocking and serious reduction of yield at wider spacing.

Some fertilization trials in young stands have been undertaken in this region as part of an interprovincial forest fertilization program, both in pine and spruce. Results within this region have been inconclusive.

A thinning plus fertilization trial in 72-year old lodgepole pine resulted in a mean increase of about 60% in dbh increment in the first 7 years after thinning. There was an additional 30 percent increase in mean dbh increment during the first 7 years following fertilization with N. Tree growth was unaffected by P and S application nor was there any significant interaction between P and N or between P and S. The author of lodgepole pine report suggested, from a cost-benefit standpoint, these results indicate little support for fertilizer use in lodgepole pine management, particularly in view of rising costs of fertilizer.

Growth and yield

Intensive forest management requires accurate estimates of current growing stock and future growth and yield under different conditions and treatments.

A long-standing growth and yield program in lodgepole pine was recently completed at NoFRC. Results have been analyzed and tabulated in a major report which records variable density yield tables. Those tables have wide application for management purposes. They assist those agencies in determining allowable harvests within stands of different ages, on different sites, and at different densities. They also provide a structural description composed of growth within natural stands. These data also assist in development and testing of stand simulation models.

The Northern Forest Research Centre is currently testing a growth model called STEMS (Stand and Tree Evaluation and Management System). It was developed at the North Central Forest Experiment Station of the U.S. Forest Service for species and conditions that also occur in this region. In tests based on local data, the model gave satisfactory growth and yield estimates for aspen and jack pine. Work is in progress to calibrate the model for lodgepole pine and white spruce. The model has been designed to project growth of multispecies stands. Its anticipated main uses will be updating forest inventories, and forecasting the outcome of different silvicultural treatments.

7. Forest Protection: NoFRC Contributions, Past and Present

An integral part of forest management is the ability to protect or at least significantly reduce damage to forests by fire, pests, and more recently air pollution. The Northern Forest Research Centre, for many years, has supported strong research programs in these areas. A qualification is made here, similar to that which prefaced the previous section. That is, a complete historical and current account of all protection oriented research is not the purpose of this report. Forest pest research in particular, has a long and highly productive record of very basic studies commencing with the late 1940's. This report focuses on those programs which have a high profile and degree of relevance vis-à-vis the already described move to more intensive forest management. Again, as in the forest renewal research program, regional management agencies to a large degree determine the direction and emphasis of protection research.

Forest fires

It is correct to say that fire, with rare exception, ranks with soil and climate in determining the unique characteristics of the forests we know today, in this region, as the boreal, subalpine, and montane. One characteristic of those forests is the virtual mosaic of different age classes, a reflection of fire history. Costs related to fire protection exceed by considerable, any other single cost of forest management.

It is conservatively estimated, prior to European colonization, naturally caused fires removed at least one percent, as a long term annual average. During the past 100 years in the west, man's activities have increased the incidence of fire by two-fold. Statistics averaged over the past 10 years record 9,000 forest fires per year in Canada, of which 32 percent or nearly 3,000 are caused by lightning. Lightning fires play the largest role in total acreage burned, i.e. 85 percent.

Despite the greatly increased ignitions stemming from man's activities, fire management agencies have reduced the total area burned from that of over 1.0 percent annually to 0.3 plus percent. Even greater reductions have been made in acreages burned within high value managed forests. The Northern Forest Research Centre research and development program has made significant contributions towards that improved fire management performance in both this and other regions of Canada.

The effectiveness of the fire control operation is dependent in large part upon an agency's capabilities in forecasting, detection and suppression.

Forecasting

Probably the most significant single national contribution of the CFS in the area of fire control is the development (still continuing) of the Canadian Fire Weather Index (CFWI) and Fire Behaviour Indices which reflect burning characteristics of local fuels. These Indices allow fire management agencies to forecast and subsequently plan by identifying degrees of fire risk within different zones of their regions. Resources can thus be assembled or alerted. The CFWI is in place in all provinces and territories in Canada and acclaimed by those agencies responsible for forest fire management and control. The Northern Forest Research Centre has made and continues to make regional contributions towards improving effectiveness of that Index.

Forests are highly burnable fuels in the broadest sense. The ease at which that fuel ignites, the rate at which the fire spreads, the intensity at which it burns differ greatly in both time and space. The age of the forest, its structural compositions, woody volume, location (slope and aspect) and type of combustible debris on the ground and on the tree stem, time of the year, day length, past and current temperatures, precipitation, wind are the principal factors which govern fire risk and behaviour. Each of those factors in turn are fragmented into numerous sub-components.

Essentially, the FWI converts effects of climate, i.e. temperature, precipitation, relative humidity and wind, on moisture contents and retention characteristics of three fuel types on the forest floor: fine fuels on the surface such as twigs, loose needles, dried grasses, etc.; upper 2 inches of forest duff such as compacted and

decaying needles and grasses; and the lower or deep duff layers down to several feet (where it exists) and consisting of organic matter in varying states of decay.

While the FWI index represents a single index most reflecting fire intensity (energy output), three components intermediary to its final calculation, have value in themselves. These are the Initial Spread Index (ISI), the Drought Code (DC), and the Build-up Index (BUI). The FWI output is in the form of numerical ratings, calculated on a daily basis by use of mathematical equations or charts. The indices are site specific to the extent of site specificity of the climate measurements. The FWI is standardized across Canada. It is the backbone of the fire forecasting system used by all fire management agencies.

A major research activity underway within this and other regions is directed towards development of burning indices (BI). These are indices which characterize the fire behaviour within specific types of forest fuels, e.g. slash, standing forests of lodgepole pine, black spruce, etc. These indices, and the data which enter into their formulation are integrated with the CFWI. The value and forecasting feature of that index are greatly enhanced with respect to its forecasting risk and difficulty of control. For operational use the CFWI's are stratified into levels of risk, e.g.: Indices 0-2, low risk; 3-8, medium risk; 9-16, high risk; 17-24, extreme risk; over 24, ultra extreme. These levels of risk, here indicated in generalized fashion, also relate to degree of difficulty in suppressing fires.

Development of burning indices (BI's) is a dangerous business and requires major participation by forest management agencies. The

risks arise because fires are deliberately ignited and the local weather can, within a short period, alter risk from a tolerable level with consequent chances for fire escape. Nevertheless, the information is so vital, management agencies support these types of experimental burns. The design of the experiments is complex. The volumes, distribution and types of fuel are inventoried in detail. Throughout the experimental area remote monitoring stations are established to record characteristics of the advancing flame front, i.e. rate, height, temperature, winds, degrees of energy released with respect to the different fuels. These fire behaviour measurements are integrated into the Fire Weather Indices and the various components of that Index.

Regional burning indices and information relating to those indices have been described for lodgepole pine, jack pine, and spruce-fir slash, i.e. debris remaining following harvest. Burning indices have been completed or are in that process in forests of lodgepole pine, and jack pine cladonium fuel types.

A recent development in the acquisition of forest fire behaviour knowledge in different fuel types and at different CFWI levels has been large-scale burning experiments in remotely located stands of timber. The NoFRC has co-ordinated the fire behaviour studies in two such experiments completed in this region. Fire research specialists from across the nation have made contributions. One burn was in the area of Darwin Lake in northern Alberta, the other near Porter Lake in the Northwest Territories. Highly useful data were obtained from both studies, particularly relating to behaviour of fire in weather and fuel conditions at the upper levels of the CFWI.

Detection

The Northern Forest Research Centre has made significant contributions to the establishment of detection networks for several of the regional forest management agencies through assistance in the location of fire tower location sites. Working in close co-ordination and with logistic support from the agencies, networks of sites were selected which optimized ground surveillance with respect to "seen area visibility" at each site, their ease of supply and communication, and their integration with systems of aircraft despatch and patrol. An improved portable fire location/finder system for use in fire towers has been developed and will be in operational use in the current year.

The NoFRC pioneered and adapted the use of the AGA Thermovision 750, a portable infrared scanner that can detect surface temperatures as small as 0.2°C from deep in the ground from heights of greater than 100 meters. It is able to locate hot spots on the ground which are not detectable by on-ground inspection. It was adapted for use in both helicopter and fixed-wing aircraft. That development has been of inestimable value in mopping-up operations following fires and in detecting potential hot spot flare-ups in ongoing fires which could expand and escape control if left unattended. It is in use now in many fire management agencies throughout the world.

Suppression

Modern fire management utilizes an age old principal which states "get there quickest with mostest". In fire suppression tactics that implies attack fires before they reach a size requiring major resource input. Time is important and the suppression tools must be capable. Hence, successful fire management requires a highly effective initial attack strategy and resource capability.

With the advent and availability of modern communication, high performance aircraft, heavy machinery, flame suppressant liquid retardants, computer technology and highly trained fire specialists, managers are increasingly successful in their ability to attack and suppress fires while small (spatially), and to greatly reduce potential acreage burned by fires which escape early suppression operations. Northern Forest Research Centre has concentrated much of its fire research resource in fire suppression work.

All aircraft used for airtankers in fire suppression within this region, are of World War II vintage with a few exceptions. They are propeller driven and usually land based of bomber type, e.g. B-26 Mitchells. The last decade has witnessed the introduction into fire suppression of the DC-6. This is a large four engined, propeller driven, more modern aircraft, able to deliver up to 2000 gallons per drop. More recently large helicopters such as the Bell 204 and Hughes 500 have come into common use and supplement the capabilities of the fixed wing aircraft.

Effectiveness of these aircraft and helicopters has been assessed by the NoFRC. No two are the same with respect to range, load

size, delivery speed and often height drop and its patterned distribution on the ground.

Assessment trials take the form of extensive ground sampling following carefully prescribed air drops, at varying speeds and heights. Frequently, unsatisfactory air drop performance is related to the gating system within the aircraft which in turn affects the spacial characteristics of liquid mass as it leaves the aircraft or helicopter bucket. By these studies, modifications for improved performance and optimum performance specifications regarding aircraft and helicopter capability have been described. Controlled air drops are supplemented by observation and measurement of tanker performance on wild fires.

Study and assessment of water thickeners and of chemicals which improve fire retardant qualities of water constitute an important program at NoFRC. They are expensive additives and together with the airtanker constitute a major item in fire suppression costs. The effectiveness of these water additives in slowing or extinguishing fires is known to vary with concentration, mixing, and delivery efficiency. The NoFRC program has provided much useful data on the characteristics of a large range of retardants. One result has been that water thickeners and retardants with short-term qualities have been found of low cost/effectiveness. They have subsequently been phased out of use. Significant savings in costs have been realized by management agencies. Other studies have provided guidance for the greater use of water, and more selective use of long-term retardants.

During fire "busts" airtankers and helitankers must not be unnecessarily delayed on the ground. Where retardants are being used,

it is important systems be in place to rapidly mix the retardant with the water ensuring the correct viscosity, and with speed, recharge the tank or buckets. Hardness and chemical constituents of the water create other problems. Quality control procedures have been delineated from study results at NoFRC and in the field. In addition, a portable retardant mixing system for helitankers was designed and tested. It is in operational use.

Fight fire with fire. The concept is age old, but only recently has it had common application to modern forest fire management. This has come about by advances in techniques of ignition, better understanding of the physics of fire, improved capabilities in application. The NoFRC pioneered work in the area of rapid and consistent fuel ignition at high speed, using helicopters. The technique was an adaptation and modification of an Australian system using celluloid incendiary capsules, a rapid ejection mechanism from the helicopter and a self-combusting mixture of chemicals which burst into flame when on the ground. This system has been in operational use for several years and NoFRC is pleased to have played an early role in its development.

Utilization of initial attack resources has been aided by development of resourcing models. The NoFRC has been active in the design of these models, still under development. They permit the fire manager to examine probable results of different initial attack strategies in a time frame of minutes. Field trials show considerable promise as important aids to fire managers.

Fire history

The common perception of fire on forest lands is frequently one of ecosystem devastation. Yet, without fire as a natural component few commercial forest stands would be available for harvest. The forest sector industry as we know it today, would not exist. The reason is that natural occurring fires act by continually renewing forests to young vigorous states. Forests, like all living organisms, go through a life cycle, i.e. germination from seed, long period of rapid growth, period of maturity and little or no growth, weakness and decline in tree and stand vigour, finally decadence and decay. Fire has acted to forestall the latter part of the natural cycle, i.e. overmaturity and decadence, over much of the boreal and montane forests. Without fire, forests would remain for many years in states of decadence and slow decay, of no commercial value and often little recreational value.

The problem with natural fire however is that it occurs in a random and unpredictable manner. Not only are decadent stands destroyed, but frequently stands either just recently established, or well into their growth cycle, vigorous and productive. The role of fire in the establishment of specific forest stands is not well understood. The Northern Forest Research Centre supports a study whose objective is to provide such historical stand data. To date, results have provided several regional agencies with information to aid in upgrading large mammal habitats, and the establishment of fire suppression action zones. Studies continue.

Forest pest management

The term pest is used to designate those insects and fungi which have injurious effects on forests designated for use by society, i.e. wood fiber, parks, shelterbelts, residential trees, etc. A distinction needs to be made because insects and fungi play an essential role in maintaining vigour of forest communities by removal of decadent stands and ground debris through degradation and decay with subsequent contribution to fertility of the forest soils.

While massive insect and fungi problems do not afflict forests within the region served by Northern Forest Research Centre, management agencies have a keen awareness of such problems in neighboring regions. For that reason they rely heavily upon the NoFRC scientists and technicians to provide laboratory and advisory services, undertake impact assessments and determine distribution and rates of spread or decline of specific pests. Many of these services are undertaken with special funding provided by the management agency.

Forest and tree pest services are administered under two separate sections. The larger, the Forest Insect and Disease Survey (FIDS) handles much of the extension work. They provide specialists for identification of organisms, appraise impact, establish systems for detection and determination of distribution. They provide these services to the provincial, industrial, and federal management agencies. The Northern Forest Research Centre FIDS are a regional link in a national FIDS program which stretches from British Columbia to Newfoundland. National goals include providing statistics on species abundance, distribution and impact, and other data for central

compilation and nation-wide distribution. Each region has its own unique forest management insect and disease problems and the regional FIDS responds appropriately. Extensive collections of identified insects and of fungi are maintained at the NoFRC. These are utilized by specialists who provide essential information to many of the pest management studies and a service to national and international co-operative programs.

FIDS responds to problems other than those caused by insects or fungi. Damage from winds, winter damage, and pollution are all assessed by FIDS specialists as requested by forested land managers, be they of timber, recreation, or wilderness value.

Forest pest problems requiring a longer term and more detailed examination are investigated by research scientists. A long-term and highly productive study is underway at NoFRC, dealing with a virulent pine stem gall rust. This gall rust poses a potential threat to young pine in both plantation and naturally established stands. Another study, more of a survey type, involves determination and measurement of mortality factors influencing survival of regeneration following logging.

In the past, within this region, research into pest management problems were essentially basic. One such study involved the larch sawfly. That insect historically created major devastation within stands of larch throughout this region. The research resulted in introduction of a hyperparasite which appears to have greatly reduced the ability of the sawfly to create the damage as recorded in the past. If so larch might well become an important community forest

species within this region. Another study involved the mountain pine bark beetle. Basic information gained from that study has contributed to management control methodology which will greatly reduce the impact of that major pest of lodgepole pine. These basic studies have been greatly reduced over the past decade, but applied studies have been maintained. Particular attention is being placed on determination of impact of specified pests such as wood borers, bark beetles, defoliators, particularly as they affect deterioration of trees of sawlog or pulp wood value. Practical cost effective controls of wood boring insects in particular have been researched, but without success. Emphasis is now placed on improving salvage opportunities through studies of impact, seasonal behavior, rates of tree deterioration. Pine stem rusts and root inhabiting fungi are being assessed in respect to their impact on regeneration. Considerable attention and funding in the past was directed towards the Dutch elm disease, particularly in southern Manitoba, emphasizing identification, detection, and distribution.

NoFRC, through its pest management program provides advisory services to home owners in rural and urban locations; provincial, municipal and federal parks administrators. Such services are in demand as aesthetic values of trees and shrubs are high. A survey carried out by FIDS in a large urban center indicated home owners placed average values of their trees and shrubs at a conservative figure of \$50 (in 1973 \$). That multiplied by the numbers of home owners throughout this region, equals a large sum. This fact, together with increased utilization in all wooded parks results in continued pressure from regional park managers and the public for expanded services.

Publications and reports have been produced and distributed in large numbers from the pest management program. They have been directed to management agencies and the public sector. All major or minor pests affecting forests, parks, shelterbelts and residential ornamentals plantings are included. One major report on tree rusts has been completed. Two more are nearing completion, one dealing with regional insect pests, the other with regional fungi and their disease symptoms. Both will be of use to resource managers and the public as well.

Impact of airborne pollutants on forest vegetation

This is the most recent major program established at Northern Forest Research Centre in the area of protection. The federal government, the public, and regional managers, particularly those with environmental mandates, recognized that growth of petroleum and heavy metal mining and processing industries create potential detrimental impacts on adjacent forested land and its soil base. This regional program is tied into national programs, as research results have application in all other regions of Canada.

Pollution is modern man's contribution towards injury of the biosphere. To date this region has been spared the "acid rain" or SO₂ problems of eastern Canada. The impact of this form of air pollution, together with NO_x and that of heavy metals upon regional forests from the growing industries of the west are nevertheless monitored. Technology and methodology for doing so has been developed at NoFRC.

The air pollution program has two main thrusts. Basic and long-term research directed towards better understanding of the biochemical, physiological, and etiology response of vegetation to common airborne industrial pollutants. To date those studies have been highly productive, providing information which is applied in the other important program, establishment of biomonitoring stations within the forested region.

That involves providing assessments and biomonitoring services to forest land and/or environmental management agencies; provincial, industrial, and federal. The research program requires an extensive array of highly sophisticated and expensive analysing equipment,

special "one of a kind" fumigation chambers possessing extensive and complex controls and measurement instruments, high quality greenhouse facilities. Such equipment and facilities are in place. NoFRC has attained national and international status for results arising from their research.

The concept of utilizing vegetation to monitor presence and impact of airborne pollutants was not originated at NoFRC. However, researchers and their support staff at NoFRC have developed that concept to the highest level and have applied it in all regional provinces and territories. In particular, extensive and complex biomonitoring plots have been established in the tar sands area of Alberta at the request of and with considerable financial support of that province. Likewise, biomonitoring plots have been established in two locations in Manitoba in the vicinity of heavy metal processing plants, again at the request of and with considerable financial assistance from that government. Those biomonitoring "stations" are examined and assessed on a regular basis.

Studies are also underway at NoFRC on the environmental effects of uranium mining, milling and waste disposal practises on the terrestrial environment. While most technical authorities agree that the short term environmental consequences of current practises are minimal, public concern has been expressed regarding the less well understood long-term effects. Research at the NoFRC is directed at understanding the mechanisms and extent to which the radionuclides and heavy metals associated with existing and abandoned uranium operations in northern Saskatchewan find their way into the receiving terrestrial environment.

Advisory services requiring somewhat less of a commitment are provided to all management agencies, on their request, for such emergencies as oil well or pipeline blow-outs, oil spills, polluted water spills on forest floor, airborne dust from sulphur stockpiles, cement plants, and potash mining operations.

The NoFRC airborne pollutant program is associated with the national federal program on Long Range Transport of Air Pollutants (LRTAP).

9. Climate and regional forest biomass

The occurrences of historical climate change is a subject of recent interest by resource economists. Climatologists have documented major fluctuations over the past several hundred years. The Northern Forest Research Centre is researching the occurrence of climatic fluctuations within this region with the intent to relate changes to growth and yield of forest biomass. It is well appreciated regional forests did not likely evolve under constant or uniform conditions. Rather, they reflect historical climates, the occurrence and qualities of which are not well known.

The NoFRC is examining climatic records, actual and proxy, to establish occurrence, extent of change and duration of past climates. Research is in-house and by contract. Extensive use is being made of "state of the art" advances in dendrochronology. Literature surveys are underway to compile records from climatic stations and proxy records of climate which relate to the boreal forest zone.

The federal government, as part of its energy conservation and alternate source programs has assigned the Canadian Forestry Service as the lead agency to investigate the potential of the forest biomass.

Biomass equations have been developed which allow calculation of whole tree and stand volumes on a cubic basis, for 10 of the major tree species within this region. Literature surveys are underway to compile data banks of growth, yield, and biomass within regional forests. Biomass volume and yield tables have been determined for young aspen stands, and stand growth models are being developed.

10. Land use classification

National Parks

A high level of capability is maintained at Northern Forest Research Centre in the area of forested and arctic land classification. A major land classification program has been completed in both Banff and Jasper National Parks. New programs are underway in Kootenay, Glacier, and Mount Revelstoke National Parks. These programs receive full field support from National Parks. Considerable development of land classification methodology was required to advance these programs. The Alberta Institute of Pedology plays a co-operative role. A highly detailed inventory of vegetation, soil, topography, wildlife, and fishery resource is now available to park managers. By close association with the teams of scientists working out of NoFRC, during their classification work, park personnel are more knowledgeable and better able to utilize the information arising from the program. Location of facilities, special-use areas, etc. can be planned now with better appreciation of the ecological system, how they will be affected, and how they will respond.

Arctic lands

Expertise at Northern Forest Research Centre in the area of arctic lands is heavily utilized by federal agencies charged with managing development and protecting the environment of the region. Major contributions have been made. Vegetation and soils in the Mackenzie corridor and along proposed pipeline routes in the Keewatin District of the NWT were classified as to composition, structure and

sensitivity to damage from industrial development. Assessments have been made on other major pipeline proposals. Contributions are made on assessments of impact and the development of environmental guidelines for major highways, oil well drilling sites and construction of gas treatment plants. A herbarium of arctic vegetation is maintained at NoFRC.

11. Remote Sensing

Remote sensing, i.e. aerial photogrammetry and satellite imagery development and methodology programs have been underway for many years at Northern Forest Research Centre. Progress in any particular aspect of NoFRC program has almost always involved close co-operative work at the operational level, with the client agencies. Over the years the remote sensing laboratory has built up a facility of considerable interpretation capability. Management agencies throughout the region utilize that capability.

Use of satellite imagery in delineating recent forest fire histories over large tracts of remote northern areas is currently under study. In the past satellite imagery has been used to delineate winter damage to lodgepole pine on the eastern slopes of the Rockies, rates of spring snow pack melt in the high basins of the Rocky Mountains, broad delineations of vegetation types and topography in remote areas.

There is a lack of inventory information in the Northwest Territories for forest management. Compounded by the vast area, poor access, and rising costs of acquiring forest inventory data, a need has arisen to develop a survey technique to augment ground surveys. Increased spectral, spatial, and radiometric resolution are characteristics of the thematic mapper (TM) on board Landsat-4, and an investigation is underway to assess its capabilities to meet this information need. Since actual TM data is not available, airborne scanner data was flown in July, 1982 (1981 proposed flight was unsuccessful), by the Canada Centre for Remote Sensing for use in a TM simulation project. The major objectives are to develop methodologies,

and to assess the type of data to be obtained from the TM using computer-aided image analysis techniques, for forest and land cover classification, at a level of detail greater than that possible with data from the previous Landsat satellites. It should be noted that the variability of forest and land cover types is one of several difficult problems in classifying lands north of 60° latitude. The ARIES II image analysis systems at the University of Alberta and the Alberta Remote Sensing Center are being employed.

12. Hydrology

Research into the impact of vegetative manipulation, including logging upon mountain and foothills watershed has constituted a major activity at the Northern Forest Research Centre since the early 1960's. Research is guided in large part by the Alberta Water Research Program (AWRP) that is a provincial/federal co-operative research program directed towards optimizing water production in the Saskatchewan and Oldman River headwaters. Other federal agencies contributing to that program are the Atmospheric Environment Service (AES), the Inland Waters Directorate (IWD) and the Canadian Wildlife Service (CWS). As owners of the land, the province of Alberta contributes and protects extensive areas of experimentation, provides large amounts of operational funding, and plays a lead role in definition of program goals.

The NoFRC is charged with co-ordinating the research aspect of the program and undertaking the principal research studies relating to the land use/hydrologic cycle. The goals of the NoFRC study are: to provide land managers with practical prescriptions and/or guidelines for stabilizing or improving the quantity, quality, and/or regime (run-off characteristics) of run-off from forested watersheds; to determine the impact of existing forest harvest practise on water yield, quality, and regime.

As a result of studies at this Centre and in experimental areas, much knowledge has been gained with respect to impact of logging and vegetation manipulation. Nearly 100 publications have contributed to the world literature and provide guidelines to forested land managers.

The world's first multiple catchment evaluation was completed

within foothills located forests. It was determined normal clear-cutting operations can increase water yield by at least 27 percent.

An important objective of these studies is to develop simulation models which incorporate the hydrologic and other land-use variables. Regional land managers thus will be able to utilize such models as an aid to making decisions regarding treatment in particular types of forested land. Such models are now available and under test. Some have been developed in-house, others adapted from other sources.

The size range of forest clearings that are effective in altering snow accumulations and melt quantity and timing has been ascertained in forests of the foothills and mountains. Early results from the first such Canadian studies on the effect of forest clearings on steep mountain slopes ranging in size from 15 feet to 1000 feet diameter, have been analyzed. Optimum clearing size was approximately 100 feet in diameter, with significant diminishing gains to 2-300 feet. The measurements of water accumulation and loss from instrumented experimental basins will need to continue. That data is only reliable if collected continuously for a period of time no less than a decade.

A range improvement vegetation treatment applied to a grazing and big game habitat in the low foothills, significantly improved the local stream flow, in quantity and regime.

The first practical method for determining the rate of water movement in stems of large trees has been developed. This permits good estimates of total water lost from watersheds through transpiration from the crowns.

Results from these studies have application beyond that of

water management alone. The models being developed are essentially land use models and can provide managers with the capability of assessing different uses and their interactions upon each other.

13. Facilities

The Northern Forest Research Centre is housed within a building constructed specifically for the Canadian Forestry Service and completed in 1970. At that time, CFS research centres in Winnipeg, and Calgary were closed and staff were assembled in the new facility in Edmonton.

The building is well suited to serve modern forest research programs. It comprises near 129,032 square feet of which 83,082 is designed as laboratory, offices, conference, and special use.

Laboratories are equipped to serve the special needs of the scientists and research foresters. Extensive controlled environment facilities are in place, as are specialized "one of a kind" controlled fumigation chambers. Six thousand square feet of quality greenhouse space is available and fully utilized, in three separate houses served by a central header house. Proficient research instrument/equipment serving and development capability is maintained within the Centre. An up-to-date soils laboratory is well equipped and able to process with efficiency, soil samples in high volume. A photographic section provides able support to both laboratory and field programs. Complete library services of a high order are provided on site, housing extensive collections of relevant journals, texts, government documents, and tied into a national system. The NoFRC have in place computer facilities and biometric services of considerable capability. That support program provides the research staff with superior data processing, systems analysis, and simulation modelling services, and data storage.

The administrative support necessary to maintain programs

and facilities such as have been described in previous sections, deserves special mention. Their contributions are seldom acknowledged. From the budget processing, through to maintenance of personal files, accounts, purchasing, stores, reception and secretaries, all provide essential services. The administrative staff can be secure in the knowledge they contribute in important ways to fulfillment of the NoFRC research goals.