FOREST INVESTMENT: A CRITICAL LOOK

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and W.D. BAKER, Cochairmen

FORESTRY CANADA

ONTARIO REGION

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FOREWORD

The symposium "Forest Investment: A Critical Look" was held at the Valhalla Inn in Thunder Bay, Ontario on 15 and 16 November 1988. It was sponsored by the Ontario Forestry Research Committee (OFRC), which was formed in 1986 as a technical committee of the Ontario Forestry Council. Its purpose is to establish the direction, priorities, execution and dissemination of forestry research with respect to the needs of forest management in the province of Ontario. This symposium was held under the auspices of the Canada-Ontario Joint Forestry Research Committee. These symposia provide a forum for discussions and exchange of ideas among provincial, industrial and research foresters working in Ontario.

The main purpose of the symposium was to take an objective look at the direction of our research programs. It was designed to generate interest among decision-makers in industry and government in addressing the question: "What information is needed to make proper decisions?"

Two hundred and seventy five delegates representing the Ontario Ministry of Natural Resources (OMNR), the forest industry, Forestry Canada, universities and other agencies as well as a small contingent from neighboring provinces and states, attended the symposium.

The symposium began with a keynote address entitled "Making the right decision for our money", which was delivered by Mr. E.F. Boswell, President of E.B. Eddy Forest Products Limited of Ottawa, Ontario. As chairman of the Ontario Forestry Council, Mr. Boswell also gave a brief account of OFRC, its origin, mandate and objectives. This was followed by the formal presentation of some 17 papers in five sessions: 1) Economic objectives, supply and demand, 2) Optimal harvesting, 3) Prime site, 4) Multiple use--impacts on wildlife, 5) Tackling the unknowns. In a poster and model demonstration session additional information on recent research investigations and findings was presented in diverse areas such as geographic information systems, wood-supply analysis, growth and yield projection systems, cost-benefit analysis, harvest scheduling and optimization techniques, wildlife management models, and expert systems. The symposium concluded with a thought-provoking discussion about the questions "Where does this take us?" and "Where do we go from here?"

The cochairmen extend their sincere thanks to Dr. F. Miller (formerly with OMNR) for her initial contribution to the program outline and to Messrs D. Ketcheson, M. Litchfield, K. Armson, J. Smith and J. Naysmith for moderating the symposium sessions. Special thanks are also due to Bill Baker (OMNR) and his assistants for making all the local arrangements.

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BACKGROUND AND ORGANIZATIONAL STRUCTURE OF OFRC

E.F. Boswell
Executive Vice President
E.B. Eddy Forest Products Ltd.
Ottawa, Ontario

The Ontario Forestry Council (OFC) was created late in 1984 to advise the Minister of Natural Resources on matters related to forestry research and development in Ontario. Once the OFC was formed, it expanded its own mandate. It now has eight members: four from industry (senior executives or chief officers), one each from the academic world and the federal and provincial governments, and a chairman. The first meeting was held in January 1985, and a series of additional meetings was held within the next six months.

Members of the OFC made it very clear that they did not believe the forest industry was being well served by the various research organizations in the province. Their perception was that there was overlap and duplication, both of activities and of advisory bodies. For the next couple of years, OFC members continued to examine these research organizations in an effort to determine the type of structure that would be most useful to industry and provincial government foresters.

In 1986 the OFC commissioned a report on the organization of management in forestry research in Ontario. The report was prepared by Bernie Burgess, ex-president of the Pulp and Paper Research Institute of Canada. It set forth some alternative structures for the OFC to consider, and weighed the implications of each alternative.

Members of the OFC now believe that the creation of an Ontario Forestry Research Institute, in which both government and industry participate, is the best solution. The federal government, however, has clearly stated that it is not prepared to participate in, or to contribute resources to, such an endeavor. At the moment, therefore, the ball is in the forest industry's court; unfortunately, the support of many major companies in the province is lacking. Sawmills, for example, are suffering from the 15% export tax, and are unwilling to contribute to the establishment of a research institute.

In the same year (1986) the Ontario Forestry Research Committee (OFRC) was formed as a result of the deliberations of the members of the OFC. The purpose and functions of the OFRC were to establish the directions and priorities of forest research in Ontario so as to meet the needs of forest management. Six subcommittees were formed to deal with what were considered the six key areas of forest research: 1) forest genetics, tree improvement, seed and stock production; 2) regeneration;

3) tending; 4) protection; 5) resource allocation, growth and yield; 6) environmental impact. These subcommittees have been asked to provide concise statements about particular problems that potential users of an Ontario Forestry Research Institute might want solved.

We have had some excellent suggestions from a number of individuals, and I encourage all of you to contribute any ideas you may have. It is essential that we give our forest managers all the tools they need to do their job.

CONTRIBUTED PAPERS

SESSION I: Economic Objectives, Supply and Demand

MAKING THE RIGHT DECISIONS FOR OUR MONEY,

OR: SELLING ON THE UP ESCALATOR

E.F. Boswell
President
E.B. Eddy Forest Products
Ottawa, Ontario

Abstract--Recent achievements in forest management in Ontario have been considerable, largely because of the existence of Forest Management Agreements (FMAs). If we wish to promote investment in our forest industry, it is imperative to sell the concept of FMAs on the province's remaining forest lands and to provide forest managers with the tools and infrastructures they need to carry out their work.

Résumé--Des progrès considérables ont été accomplis récemment dans le domaine de l'aménagement forestier en Ontario, grâce en grande partie aux ententes de gestion forestière. Si nous voulons promouvoir les investissements dans notre industrie forestière, nous devons faire accepter le concept de ces ententes sur les terres forestières restantes de la province et offrir aux gestionnaires forestiers les outils et l'infrastructure dont ils ont besoin pour accomplir leur travail.

The title of this paper is a provocative one, to be sure, but just what does it have to do with forest investment? Simply this. We in Ontario are on a "positive roll" with respect to our achievements in forest management. The resounding success of the Forest Management Agreements (FMAs) within such a short period has put us on the "up escalator". Now we must sell the concept of FMAs on the remaining forest lands (public and private), and create structures to provide our forest managers with the tools and infrastructures they need to do the sophisticated work of which they are capable.

One hundred and eighty-two years ago today, a young army officer on an exploratory expedition in the American midwest sighted a high mountain and decided to try to climb it. Before he could do so, he was taken prisoner by the Spanish for trespassing on their territory. He did not climb the mountain, but it bears his name -- Pike's Peak. I like to think of young Montgomery Pike as a man who reached for the heights, even if he did not get there. At least he identified his goal clearly.

What I want to say to you today is that, by being positive and looking to the heights, we spur ourselves on to greater levels of achievement. Let's examine how we can do this.

What factors create a positive investment climate for investments in forestry and the forest industry? There are three of them, and they should be as clear to you as they are to me:

1) stability
2) realism
3) a positive attitude (self-confidence).

Stability

The most important means of attracting investment to Ontario's forest industry have always been the stability of wood supply, and the way in which that stability is managed. A clear understanding of the potential of the forest industry depends on a strong marketing program and an assured source of fiber. Until recently, Ontario had an excellent record for helping to ensure long-term licence and volume agreements that added to the investment community's sense of perpetuity; it was a jurisdiction that always supported its exporters.

Then there occurred two of the most unfortunate events in the history of the forest industry in northern Ontario, the publication of the Woodbridge Reed report and the Temagami fiasco.

The Woodbridge Reed report was nothing but a series of banana republic-type generalizations and sweeping comments that were ill-founded, ill-conceived and indeed ill-mannered, and hurt us in the international marketplace. It was a report sponsored by the province of Ontario criticizing the marketing efforts of one of its major industries.

But I shall not be guilty of making the same sort of generalizations; I shall be specific.

The Woodbridge Reed report stated that "funds have too often been devoted to making the same commodity products... instead of looking to higher value products for the inherently smaller scale machinery."

Here are the **facts** surrounding that 1985 statement: Ontario's value-added per m^3 of wood consumed was the highest in Canada -- 41% higher than the national average, and 120% higher than that of British Columbia.

How do you think our international customers looked upon this report? How do you think my sales people in Manhattan, Boston, Knoxville and Atlanta felt about the way the report supported their efforts? Believe me, they did not feel very good. This surely is not the way to attract investment, to our forests or to any other part of our industry.

Recent events at Temagami (the issue of wilderness preservation versus harvesting) have sacrificed stability to short-term political needs. What has happened there will do more harm to the investment climate than all the grant programs and government-initiated cooperative modernization projects of the last two decades.

In terms of stability, can there be many forestry achievements anywhere in the western world more significant than those of Ontario's FMAs? Let us look for a moment at the spin-off effects of the FMAs:

1) Professional expertise, previously limited to a few people, is being developed on a wider scale;

2) Forest renewal efforts have increased 10 times in eight short years, and will continue to increase at an exponential rate, providing fiber and hence investment opportunities for our future;

3) The papers that will be presented over the next two days address some very complex and controversial subjects; could the same complex and tough-minded discussions have been held 10 years ago?

4) We have a much broader base on which to develop programs in tree improvement, genetics and biotechnology; these programs are now being discussed by senior industry and government executives, and long-term investment decisions are being made;

5) In 1988 it is estimated that $750 million of **new capital** will be spent in this province by the forest industry; can there be any doubt that the positive climate created by the FMAs is a significant contributor to that flow of funds?

6) I have outlined the efforts being made in the area of research. This research is focused on the user and, when properly managed, will result in significantly higher investment, not only in the research projects themselves but in the results that are bound to follow from them.

Here again, the FMAs and the stability they represent will enable us to be collectively tough minded about our research decisions -- decisions that must be financially profitable. For those of you who cannot accept that principle, I would remind you that, in any field of endeavor, if you want to know the true **value** of your work, try to borrow some money to finance it. That brings to mind my favorite anecdote about achievement.

> "At the end of a year in the world, a young man came home and told his father he was worth $100. His father simply smiled. The following year he reported that he was worth $1,000; his father still smiled. Year after year as he came home and reported how much he was worth, his father was merely amused. Then, one year the son came home and said: 'Father, this year in order to keep the business going, I had to borrow a million dollars.' His father clapped him on the back and said: 'Now **that** is an achievement.'"

The list of stabilization and investment-stimulating projects that the FMAs will generate is endless. It is a success story of major proportions. But let us remember Irving Berlin's words of wisdom: "The toughest thing about success is that you've got to keep on being successful."

Realism

Although stability is essential in the forest industry, so is realism. If we are to encourage investment in our forests, we must recognize the changes in the world marketplace. Consolidation, "rationalization" and productivity are all elements of that change. Consider, for example, that Ontario, with 18% of the softwood lumber establishments in Canada, produces only 7% of the country's total softwood lumber. Can it be very long before British Columbia, with a mere 8% more establishments, yet responsible for 59% of the total production, overwhelms the marketplace and cripples our local industry? We must be realistic and invest heavily in our forests and our sawmills if we are to overcome that kind of competition.

And let us be realistic about what I choose to call the "exhaustion theory". According to this theory, the world is running out of fiber sources and, therefore, Ontario's forests present untold opportunities for the creation of wealth and generation of income for Ontario. This is patent nonsense. As long as there are prime sites anywhere in the world on which competitive forests of similar species can be grown, investment dollars will be directed to the sites on which costs are lowest. In two weeks' time I suspect I shall be able to speak to you on this subject with more knowledge and fervor as I am leaving very shortly for Brazil, where Eucalyptus trees and the pulp made from them will likely compete with Canadian products within a decade.

Brazil is only one potential source of relatively inexpensive wood fiber. In Sweden, I have been told, a large new pulp mill will be built shortly to utilize fiber available in the **southern** part of the country.

Being realistic can only spur us on to greater heights and remind us that "it is not failure but low aim that is the crime."

A Positive Attitude

The greatest single resource we all possess is our ability to eschew predictions of gloom and doom and adopt a positive attitude. I remind you of the remark attributed to Ted Turner, that pillar of ebullience: "If you think you are a second-class citizen, you are."

We, as members of the forest industry, have that positive attitude when we market our products. In Ontario we can manufacture forest products from lumber to sophisticated specialty papers as well as anyone else in the world. We must recognize that fact, and imbue other resource professionals with our positive attitude to marketing.

There is no doubt in my mind that, if we act as the resource professionals we are, we shall successfully maintain the productive forest land we require to build a strong industry for the people of this province. Often that ideal is hard to keep in mind as we struggle through competitive land issues, environmental assessment hearings and tragedies such as South Moresby, Fundy and now Temagami. If we can rise above the pettiness of so many of our critics we will demonstrate that the course we have chosen in forest land management is the correct one, and that which will lead to further investment.

At this very moment, at many of the mills in this province, we are developing new products to meet new needs around the world. It is a development effort with which many of you may not be familiar. We have achieved tremendous success in the world marketplace but our resource managers are not aware of this. It has been costly work, but as I speak, somewhere in this province a new paper product is being developed that will further enhance the value of the wood we are growing.

If you wish to know more about positive approaches to business and management, I recommend John S. Roberts' book on the Mitsui Corporation: **Three centuries of Japanese business**. There is a statement in that book that I would like to bring to your attention in the hope of giving you some confidence in our future: "In the lean years from 1945 to 1950 the only ways of getting rich were the three Ps: pachinko (pinball), pan-pan (prostitution), and parupu (pulp)." I am not sure about the first two, but I believe that, in lean years and good years, pulp and our other forest products will see this province through.

If we fulfill the mandate and achieve the objectives set out in the FMAs, there is no end to the potential investment opportunities in this industry. In closing I would like to remind you that "it is not the gales but the set of the sails that determines the way we go." I think our sails are well set. If we do not reef them too dramatically, or luff too drastically, northern Ontario will continue to be a good place in which to invest in forests and forest industry.

ONTARIO'S FOREST PRODUCTION POLICY

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Abstract.--The 16-year-old Ontario Forest Production Policy -- the basis and strategic planning framework for the Provincial Forest Management Program -- is being reviewed and revised. This paper examines why Ontario invests in forest management and outlines the challenges and opportunities that must be considered in the development of a new policy.

Résumé.--La politique de production forestière de l'Ontario qui, depuis 16 ans, sert de base et de cadre de planification stratégique au programme provincial d'aménagement forestier, fait l'objet d'une révision. Cet article examine les raisons pour lesquelles l'Ontario investit dans l'aménagement forestier et fait ressortir les défis et les possibilités qui doivent être pris en considération dans l'élaboration d'une nouvelle politique.

INTRODUCTION

The influence of forest management extends well beyond the production of wood fiber into the very fabric of our society. Ontario's forest resources provide a vast array of wood products that sustain the forest industry and generate employment opportunities in other related industries. From a socio-economic perspective, forest management initiatives also stimulate opportunities for regional economic development and economic diversity, provincial revenues, and payments toward balance of trade; they also generate an important range of social and environmental benefits including recreational opportunities, fish and wildlife habitat, and clean air and water.

Within this larger socio-economic context, Ontario's Forest Production Policy (FPP) provides the basis and strategic planning framework for the provincial forest management program. For almost 16 years, the FPP has guided the efforts of forest managers across the province. It is testimony to the architects of the FPP that it has retained its relevance as a planning benchmark for the program for over a decade and a half. It has served the government and the forest management program well.

With the passage of time, it has become apparent that the FPP must be modified to embrace the significant changes that have occurred in the program and in the broader operating environment. Among other things, the task of developing a new policy will involve a complete review of the socio-economic context of the forest industry, the current demand for forest products, the industry's prospects, environmental considerations, and forest management requirements to ensure an adequate supply of wood for the next century.

By reviewing the contribution of the forest industry to Ontario's economy, I shall examine in this paper why Ontario invests in forest management and what challenges and opportunities the province faces in redesigning its primary investment tool, the FPP.

SOCIO-ECONOMIC CONTEXT

The harvesting of Ontario's forests began almost 200 years ago. Since then, the forest industry has played a major role in opening up the province to settlement and development, and in maintaining a high standard of living.

Today, Ontario's forest industry consists of about 1,800 companies engaged in logging activities and in the manufacture of a wide variety of wood products. The manufacturing sector consists of two basic industries: the wood industry and the paper and allied industry.

In 1986, northern Ontario supported:

- half of the pulp and paper mills in the province and all but two of the large mills

- 80% of the major sawmills in Ontario

- eight of nine particleboard plants in the province

- 60% of the veneer and plywood plants in the province.

By contrast, most of the forest products industries with high value-added are located in southern Ontario, an economically diverse area.

The structure of Ontario's forest industry has evolved over time. In the recent past, there was a movement toward greater horizontal and vertical integration within the industry to achieve more competitive market positions by:

- broadening their product base

- "rationalizing" capital expenditures

- improving product utilization.

Ontario's forest industry is dominated by large and fully integrated forest products companies. Companies that until now have been independent are becoming more interdependent because of the integrated use of fiber supplies and various contractual agreements designed to ensure the economical and efficient use of byproducts. Investment by the industry in upgrading and modernizing capital has also been a significant means of maintaining competitiveness. In the last five years, the pulp and paper sector has spent $4.5 billion on capital projects. Approximately 60% of Ontario's paper-making capacity has been modernized or rebuilt.

The Impact of Regional Employment

The forest industry generates significant socio-economic benefits for all regions in Ontario. It has a particular strategic significance in northern and eastern Ontario -- areas that the province is targeting for economic growth.

The forest industry is the predominant base for industrial development in northern Ontario. More than 12 northern communities are almost totally dependent on pulp and paper mills. A further 16 communities are directly or indirectly dependent on sawmills and logging for their economic well-being.

Although the impact of the forest industry is not as distinguishable in the diverse economy of southern Ontario, it does play an important role in the economic life of many small rural communities.

Employment in the Ontario forest industry has remained relatively stable at a time when growth in service-sector employment has accelerated. The industry currently provides direct employment for approximately 72,000 people. If the industry multiplier is used, there are over 160,000 jobs in the forest sector (direct and indirect employment combined).

Contribution to Gross Provincial Product

The forest industry also makes a significant contribution to Ontario's gross provincial product, of which it accounts for approximately 6%. In 1987, the total value of shipments of forest products exceeded $8 billion, with net exports accounting for $2.44 billion. By comparison, the auto industry, another economic mainstay, exported some $3.28 billion worth of goods during the same period.

On the basis of current commodity prices and operating rates, the forest industry is expected to generate over $1.5 billion in cash flow this year.

Export Market Performance

Certain sectors of the industry are geared to serve export markets. Lumber, pulp and newsprint accounted for roughly 45% of the value of shipments and for 72% of the value of all Ontario forest products exported in 1983. The United States (particularly the central states) is the primary market for Ontario forest products, normally absorbing 95% of all pulp exports, 95% or more of all newsprint exports, and 99% of all lumber exports.

Products such as plywood, waferboard and paper of certain grades sell in both domestic and export markets. Products with high value-added, including millwork, kitchen cabinets, and converted paper products, generally serve a protected domestic market.

In 1983, the Ontario forest sector exported products worth more than $3 billion:

- $2.26 billion worth of products were exported by the paper and allied industries group (i.e., pulp, $640 million; newsprint $1.0 billion; paper products, $620 million)

- $1.01 billion worth of products were exported by the wood industries group (i.e., lumber, $745 million; veneer and plywood products, $77 million; miscellaneous millwork and wood products, more than $175 million).

Revenues

In 1986, the Ontario forest industry and its employees generated tax revenues valued at more than $0.6 billion (federal and provincial). Corporate income taxes contributed 38%, personal income taxes by forest sector employees accounted for 54%, and the residual 8% constituted an aggregate of various taxes, including excise taxes, fuel taxes, and retail sales taxes. Various timber fees and area charges yielded an additional $70 million.

The recent imposition of the 15% export tax on softwood lumber exports to the United States is expected to generate a further $22.5 million per year in tax revenues.

THE INDUSTRY'S PROSPECTS

There have been numerous analyses and projections of world demand for forest products, including forecasts prepared by the Food and Agriculture Organization (FAO) of the United Nations, the Department of Regional Industrial Expansion (DRIE) and the Canadian Pulp and Paper

Association (CPPA). Predictions are reasonably consistent at the global level for the period from 2000 to 2020. Typical of these forecasts is that of Silva Fennica:

World demand for forest products

Product group	Annual increase (%)
Sawnwood	1.1 - 1.5
Wood panels	2.2 - 4.7
Pulp	3.0 - 3.3
Paper and paper products	2.8 - 3.7

According to such estimates, the total demand for forest products, weighted by the present structure of Ontario's forest industry, will grow at a rate of approximately 3% per year.

The development possibilities for Ontario, when measured against a growth in world demand of 3% annually, are a function of:

- our ability to expand production on the basis of constraints of land, labor, forest harvest and renewal commitment

- our competitiveness in international markets, especially in product and geographical areas of high growth

- growth rates over time, which illustrate development, innovation and leadership in industry, and fiber utilization rates.

The current expectation is that growth at the rate of 1.5-2.0% a year, which has characterized Ontario's forest industries, will continue to the year 2020.

Wood, labor and transportation are the principal components of manufacturing costs for forest products, and as such will determine the long-term ability of Ontario producers to compete in an increasingly competitive market. Wood costs are the single largest component and can be expected to rise over the medium term as the industry utilizes more distant and marginal stands. Within the next half century, this trend should be reversed if recent regeneration and forest management efforts are maintained and expanded.

By sector, projections indicate a growing demand for all primary products: market pulp, newsprint, and lumber (although the effect of the recent tariff on softwood lumber exports to the United States is as yet undetermined). Domestic producers will face a difficult time during the latter half of the 1980s because of increased competition and prices resulting from the export tax. Low-cost producers, particularly in the southern United States, can be expected to take over a larger share of the northeastern United States markets, which have been traditionally dominated by Ontario and eastern Canadian producers.

In general, long-term projections indicate an increase in demand for most forest products. Opportunities for continued growth and profit in the Ontario-based industry will inevitably be contingent upon how well Ontario producers maintain their competitive positions with other producers, in view of fluctuating currency exchange rates, housing starts, and tax increases.

ONTARIO'S FOREST PRODUCTION POLICY

The objectives of Ontario's forest management program are:

- to provide for the optimum and continuous contribution of forest-based industries to the economy of Ontario and to provide for other uses of the forest through environmentally sound management practices

- to promote the stability of the forest industry by ensuring an adequate timber supply.

Ontario's FPP is the framework established by Cabinet to effect these broad program objectives.

Instituted in 1972, the FPP is a statement by the provincial government of its commitment to support the maintenance and enhancement of the forest resource so as to provide a sustained annual supply of wood fiber. Within this broad directive, the Ontario Ministry of Natural Resources (OMNR) determines the relative roles of allocation, protection, access, renewal, tending and associated forest management activities to meet the goal of the policy.

Specifically, FPP is a strategy to ensure a sustained yield of 25.8 million m^3 of industrial fiber annually by the year 2020. The current annual harvest in Ontario is approximately 20 million m^3. The implementation schedule is the translation of the volume target into a series of regional, district and management unit silvicultural treatments.

The FPP implementation schedule, set in 1973, had a 10-year span. After four years, the series of annual benchmarks for planning purposes was sufficiently at odds with what was being accomplished that a revision of the schedule's targets was deemed appropriate. This revision postponed completion of the 10-year plan by an additional three years. A similar revision of the targets was conducted in 1984. The net result of these reviews was to convert the original 10-year plan into a 15-year plan. The long-term FPP volume and area targets have remained the same since 1972.

FPP constitutes an initial attempt at strategic planning for forest management within the limitations of data and techniques. Fifteen years later, the FPP remains the policy basis and strategic planning framework for forest management. The policy has served OMNR and the forest management program well. It has been an effective tool for planning and control and for setting targets for sustained supply from a new forest. Of primary importance, the policy has been used effectively to obtain funding for the province's renewal program by placing budgetary requirements in the context of long-term needs. Since 1979, forest management expenditures have increased from $57 million to $200 million a year -- a significant rate of real growth.

TOWARD A NEW TIMBER PRODUCTION POLICY

Over time, it has become apparent that some of the assumptions upon which the FPP is based are outdated. OMNR, through the Baskerville Action Plan and the Class Environmental Assessment for Timber Management, has undertaken to conduct a review of the assumptions and forecasts upon which the policy is based to determine whether a change in the policy should be recommended. The review is scheduled for completion by July, 1989.

Among other things, the development of a new Timber Production Policy (TPP) will focus on:

- updating initial predictions about long-term industrial wood demand

- predicting more precisely the quantity and type of forest products that can be supplied from the forest

- assessing forest productivity more precisely on the basis of current surveys of soils and forest sites

- developing predictions about the level of investment (intensity of silvicultural treatment) needed to produce the type and quantity of forest products that will be required from the new forest

- making predictive simulations of timber supply in relation to demand and other factors.

In any new policy, it will be imperative to ensure that both the existing forest and the new forest are combined in a comprehensive and balanced program of forest management.

The existing forest is the sole source of wood fiber to sustain the province's forest industry over the next 40 to 60 years. The sector's 72,000 direct employees rely totally on the continuation and improvement of programs directed at the existing forest. These programs consist of improved access to the resource, improved protection from fire, insects and disease, and increasing efforts to improve utilization and marketing of less-preferred species and products.

To replace the existing forest resource and to sustain forest sector employment, production and exports beyond the year 2020, a new forest must be established, tended and protected. Specific programs in this area are concerned with tree production, regeneration, site preparation, planting, tending and tree improvement.

There are extremely long periods between investment in a renewal activity and the eventual yield of fiber. To be credible and effective, a strategic plan for forest management will require both a commitment to and provision of the following essential activities: planning, renewal, tending, protection, access, utilization, marketing, research and technology transfer.

Ontario's FPP provides both the mandate and the mechanism to support an aggressive renewal program and ensure an industrial cut of 25.8 million m^3 a year by the year 2020. Under the new TPP, this renewal effort will be strengthened and a policy directed at stretching existing forest resources will be developed. Renewal activities will focus on prime sites to meet the objectives of economy, effectiveness and efficiency.

The development of the new TPP will be undertaken in two phases:

- Phase I will focus on development of a macro-level provincial production policy, using the best available information about the resource base, markets and the current policy environment

- Under Phase II regional production strategies will be designed on the basis of data aggregated from the management unit level upward.

The basis for the development of the macro-level provincial policy will be contained in six background papers covering the history of Ontario's forest production policy; the socio-economic context of the forest industry; the demand for Ontario's forest products; stretching production from the existing forest; planning and establishment of the new forest; and responding to environmental issues. In accordance with OMNR's desire to seek means of involving local, regional and provincial groups in the decision-making process, these papers will be widely circulated to the forest industry and other affected groups for review. Government review of the new TPP is scheduled for July 1989, although it is recognized that this deadline may be adjusted to meet requirements for full and open consultation.

After the development of a broad provincial forest management framework, regional/local forest production strategies will be developed from the management unit level upwards on the basis of data derived from timber management plans. Industry involvement at this stage, through the timber management planning process, will be critical if these strategies are to be linked effectively with the broad provincial policy and are to be up to date with market conditions. It is anticipated that this process will take approximately two years to complete.

CONCLUSION

The challenge for forest managers today is to manage our limited resources for the best combination of economic, social and environmental benefits. In reviewing and revising Ontario's FPP, we in OMNR are well aware of the magnitude of our task. We must address concerns expressed by those who are actively involved in environmental protection issues. We must also ensure that the business climate for the forest sector is positive, so that we can attract new investment and keep the industry growing.

The development of Ontario's new TPP will set a precedent because it will be designed and implemented in full consultation with the forest industry, the public, and other interested groups. If successful, the new policy will guide the shape of forest management in Ontario into the next century.

WORLD DEMAND FOR ONTARIO'S FOREST RESOURCES[1]

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The most significant development among the nations of the world today is the change from a military to an economic form of competition. I believe that this shift in emphasis will have a positive effect on the forest industry in the years ahead. As this trend toward economic competition continues, there will be a tendency among nations to form economic blocs.

I also believe that the possibility of a major economic crisis cannot be dismissed. I am not a prophet of gloom and doom, but it does seem to me that, in North America, excessive consumption is one of the major problems, and we are increasing our public deficit to an alarming degree to finance this consumption. It is essential that we restrain spending so as to reduce the need for imports, and that we increase the availability of products for export.

In both the United States and Canada, there is a need to retrain people who are currently unemployed or are working in industries that now make products for which there is little demand. There is not enough productive capacity at present to meet the increased demand for certain products. The trick is to curb domestic demand and, at the same time, to meet foreign demand for North American products. Otherwise, we are in for a world recession of major proportions.

At present, the external or trade deficit of the United States is by far the most threatening of a number of serious challenges to the world economy. In my view, a vote against free trade between Canada and the United States would have the effect of lowering the value of the Canadian dollar in comparison with its American counterpart. I believe that our dollar should trade in the range of 77-78 cents, but if we reject free trade, it could easily drop to 75 cents in comparison with the American dollar.

This would not necessarily be a bad thing for the forest industry, as it would very likely mean an increase in the equity value of forestry stocks. Nevertheless, Canada must become competitive on the world market instead of relying primarily on the United States for its export trade. The main reasons we trade so much with the United States are that transportation is relatively inexpensive and that the value of our dollar is low in comparison with the American dollar.

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[1] This paper is a partial transcript of an address given by the author at the symposium.

I have taught courses in Canada/United States trade relations for 17 years now, and one of my main concerns is the potential effect on the forest industry if countervailing tariffs were applied to paper exports. If we turn down the free trade agreement we will still be vulnerable to countervailing and, in addition, we will face a hostile American Congress. We cannot afford to take these risks because, at present, 90% of Ontario's exports go to the United States.

There are other markets available, and we must take advantage of them. We must become competitive internationally, or else we face economic ruin.

MODELING NEEDS AND INPUTS FOR FOREST INVESTMENTS

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Abstract.--Models are abstractions of reality that may be used to solve problems too complex, expensive, or otherwise difficult to solve directly. Models may be used to guide investment decisions in forest management, such as choice of product or species mix, forest investment timing and location, or to identify expected costs and values resulting from forest investments. Forest investments may be made at the stand level (silvicultural) or the forest level (management). A conceptual structure of a silvicultural model is presented. Data requirements for such models may include biological treatment-response forecasts, treatment cost data, price forecasts, and local policy constraints. A sample model is discussed. A conceptual structure of a management model is presented. Data requirements for such models may include present age-class distributions, stand development options, the spatial distribution of stands comprising the forest, transportation systems, mill requirements and locations, budgets, and policy constraints. Again, a sample model is discussed.

Résumé.--Les modèles sont des abstractions de la réalité qui peuvent aider à résoudre les problèmes trop complexes, trop coûteux ou trop difficiles à résoudre directement. Les modèles peuvent être utilisés pour prendre des décisions en matière d'investissement en aménagement forestier, comme les décisions portant sur le choix du mélange de produits ou d'essences ou sur l'échéancier et la localisation des investissements forestiers, ou encore pour déterminer les coûts prévus et le rendement résultant des investissements forestiers. Les investissements forestiers peuvent être envisagés à l'échelle du peuplement (sylviculture) ou de la forêt (gestion). Cet article présente une structure théorique de modèle sylvicole. Ces modèles peuvent nécessiter des données telles que des prévisions traitement-réponse biologique, des données sur les coûts de traitement, des prévisions des prix et des données sur les contraintes politiques locales. L'auteur donne un exemple de modèle. Une structure théorique de modèle de gestion est ensuite présentée. Les données nécessaires à ce genre de modèle peuvent comprendre des données sur la distribution actuelle âge-classe, les diverses options de mise en valeur des peuplements, la répartition spatiale des peuplements qui englobent la forêt en question, les systèmes de transport, les besoins en installations et les contraintes de localisation, de budget et de politique. Un exemple de modèle est analysé.

INTRODUCTION

Models are simply tools that we use to help solve problems. Models allow some of the complexity of forest planning problems to be removed temporarily. For example, when we wish to determine the annual harvest a particular forest area can sustain in perpetuity, we may calculate and add the Maximum Allowable Depletion (MAD) (Anon. 1986) values for the Working Groups that comprise the forest. We know that this is not really the sustainable harvest level, but it gives us an approximation.

Forest managers use many models in their work. These range from simple rules of thumb for guiding daily operating decisions to complex computer programs for wood supply analysis. The models of interest in this paper include those used for planning silvicultural investments and forest management strategies. Many such models exist, but the investment planning needs arising from today's changing marketplaces for forest products often exceed both model capabilities and our knowledge of the expected growth responses of stands to various silvicultural investments. This paper provides a look at the modeling needs and related data needs that have to be met if one is to respond to these changing markets. Basic investment questions, general structures, and data requirements are reviewed for both stand-level and forest-level models. Brief discussions of sample models are also provided.

Stand-level Models

Stand-level models are used to address questions about individual stands or stand types over time (Fig. 1). These questions may relate to such items as species mix, planting density, tending regime, products, and final harvest age. In general, stand-level models are designed to forecast the biophysical, and possible economic, development of stands in response to alternative treatment regimes. Many such models have been developed, although most of these are species-specific and can take into consideration only a few alternative treatment types and intensities.

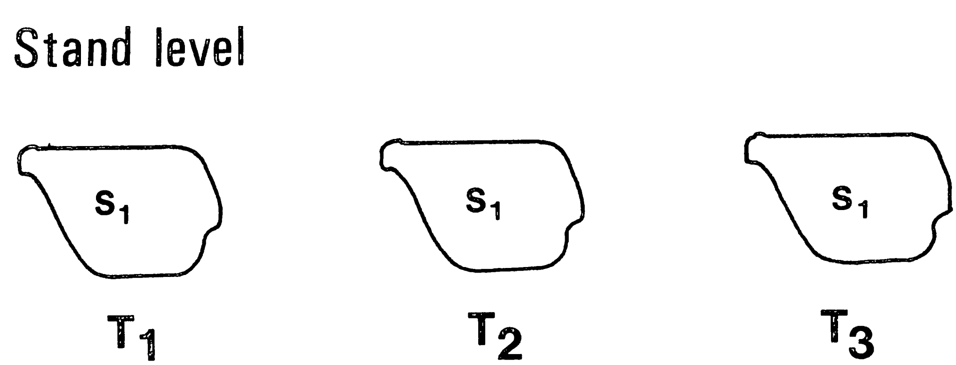

Figure 1. Stand development

The Stand and Tree Evaluation and Modeling System (STEMS) (Belcher 1981, Miner and Waters 1984) is an example of a general-use system designed to help address questions related to many species and treatment types. STEMS projects growth, including adjustments for competition and mortality, of individual stands or plots in response to alternative treatment regimes (Fig. 2). STEMS may be used to project data from several stands or plots as a series, or the microcomputer-based version, The Woodman's Ideal Growth Projection System (TWIGS) (Belcher 1982) may be used to project one stand or plot at a time. A reporting routine supplied with STEMS may be used to generate tables describing plot growth and yield over time. With the addition of some economic data, these tables may be used as the basis for assessing the economic efficacy of alternative regimes, along with an evaluation model such as QUICKSILVER (Vasievich et al. 1984).

Proper use of STEMS requires that the species-specific growth equations within the model be valid for the sites in question. These equations predict annual diameter growth potential for individual trees, adjust this for competition, and then reduce tree numbers for expected mortality. Annual growth potential is a function of current DBH, site index, crown ratio (estimated on the basis of DBH and stand basal area if necessary), and species. The competition adjustment is a function of current DBH, stand basal area, stand average DBH, and species. Tree mortality is a function of current DBH, annual growth rate, and species. Net annual diameter growth is added for all trees and translated into stand volume growth. Partial or clear cutting, and resulting regeneration, may also be specified in any year.

This process is repeated for each year in the planning horizon. Equations have been developed for most species of interest in Ontario, and are based on data from the United States. Some adjustments to these equations are necessary to reflect local conditions. Required plot data for STEMS include stand age and site index. Required tree data include a stem count by species, DBH class, condition (live or dead), and tree class (acceptable, rough, etc.). For evaluating alternative treatment regimes, some means of translating the final diameter distribution and volume estimates into product yields is also required, as are estimates of treatment costs and product values over time. Such data are not easy to obtain, but are required if we are to assess the economic returns from silvicultural investments.

Forest-level Models

Forest-level models can be used in developing strategies for managing multi-stand forests over time (Fig. 3). Forest-level models offer a framework within which forest-wide objectives and constraints can be addressed when one is considering alternative silvicultural investments in various stands. Such models are typically constructed with a modeling system that incorporates user-specified stand-level yield forecasts, age-class distributions, harvest-flow and access constraints, transportation systems, mill requirements, and objectives into a model of a particular forest. The yield forecasts may be made with the aid of stand-level models. Many such models are in use.

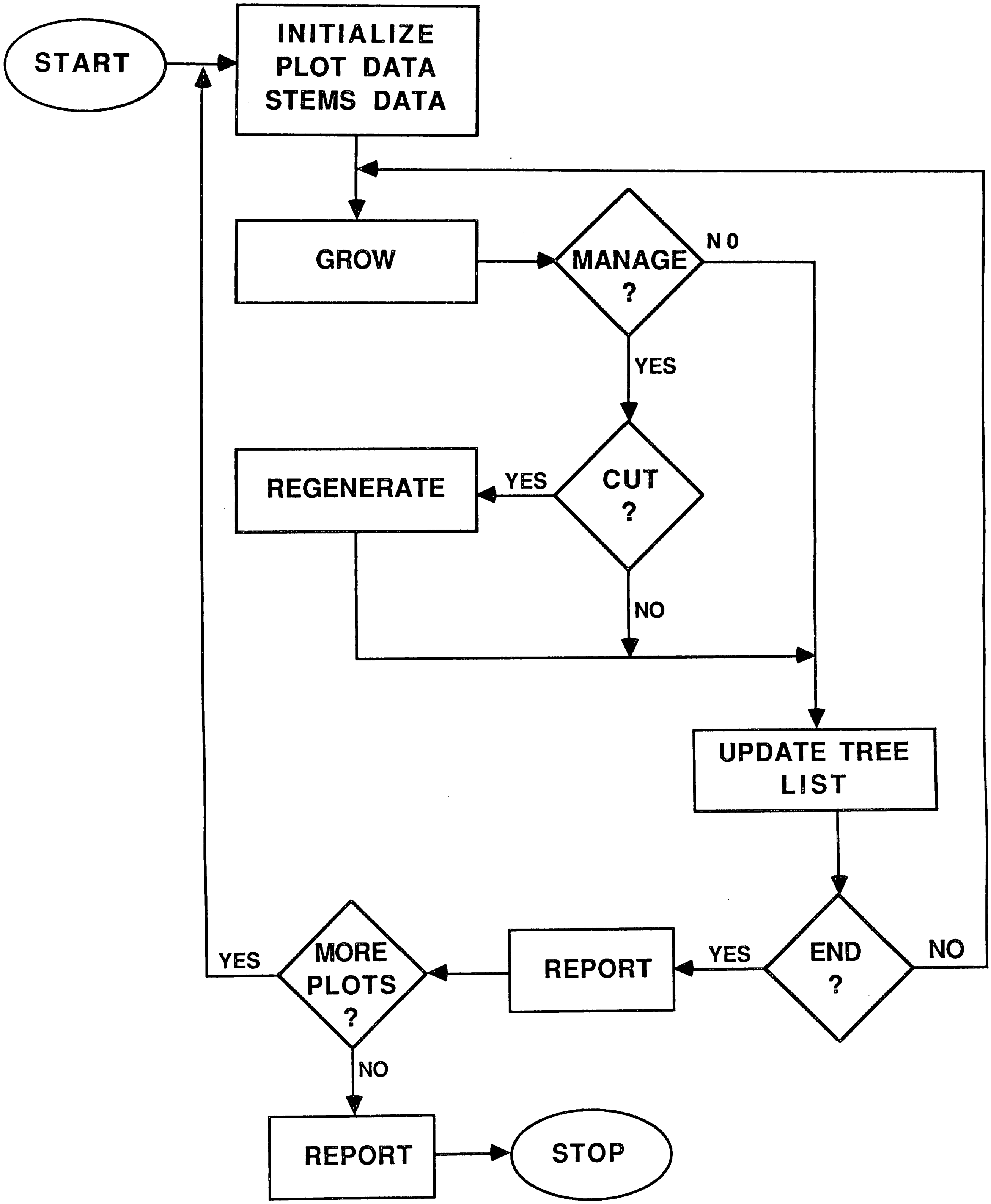

Figure 2. STEMS structure

One example is FORMAN (Wang et al. 1987). FORMAN is structured as a loop, with each pass through the loop assigning user-defined treatments to stands within one planning interval (Fig. 4). Treatments may be a single event, such as a clearcut harvest, or a treatment sequence, such as mechanical scarification and planting followed within five years

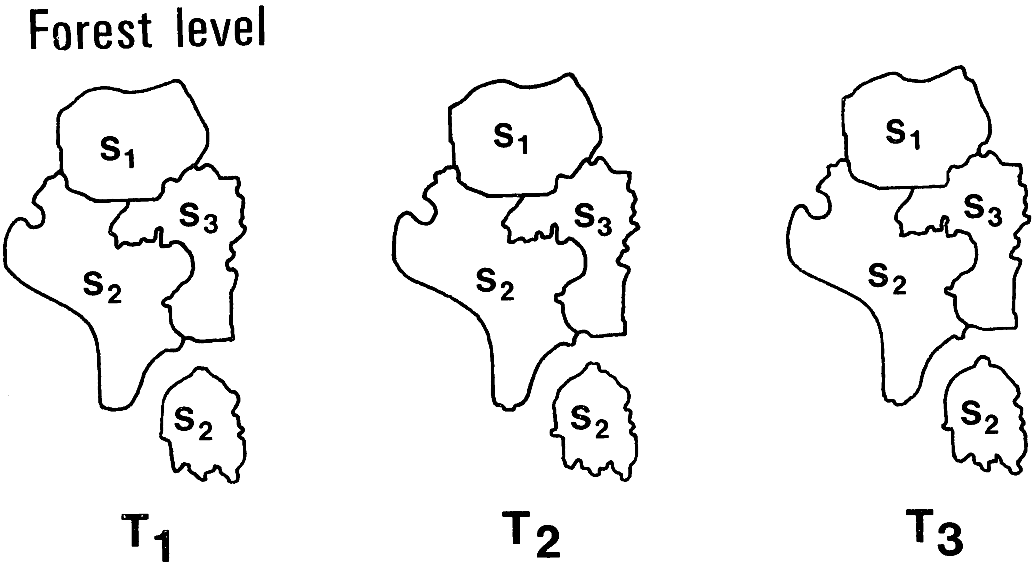

Figure 3. Forest development

by herbicide application. Three major types of treatment may be defined. Harvesting includes any treatment sequence that changes the age of a stand to zero. Planting includes any treatment sequence implemented on current cutovers. Not all current cutovers need to be planted, and not planting may also imply a treatment sequence. Spacing includes any treatment sequence that changes the expected development of an existing stand, but not its age. Treatments are allocated up to desired levels, according to user-specified forest-level criteria, such as harvesting oldest stands first or planting upland sites first. The resulting forest is then grown for one planning interval, and the loop is repeated.

The initial forest structure is defined as age-class distributions within a set of development classes and management units. Development classes are groups of stands following a common set of time-dependent curves, such as volume by species, harvest cost, and product yield. Management units are usually geographic areas, such as working circles or compartments. With care in defining management units, users may model the spatial distribution of the forest resources.

The forest structure evolves over time, in response to the cumulative effects of growth and the treatments imposed during previous intervals. After several iterations, users review the sequence of treat-

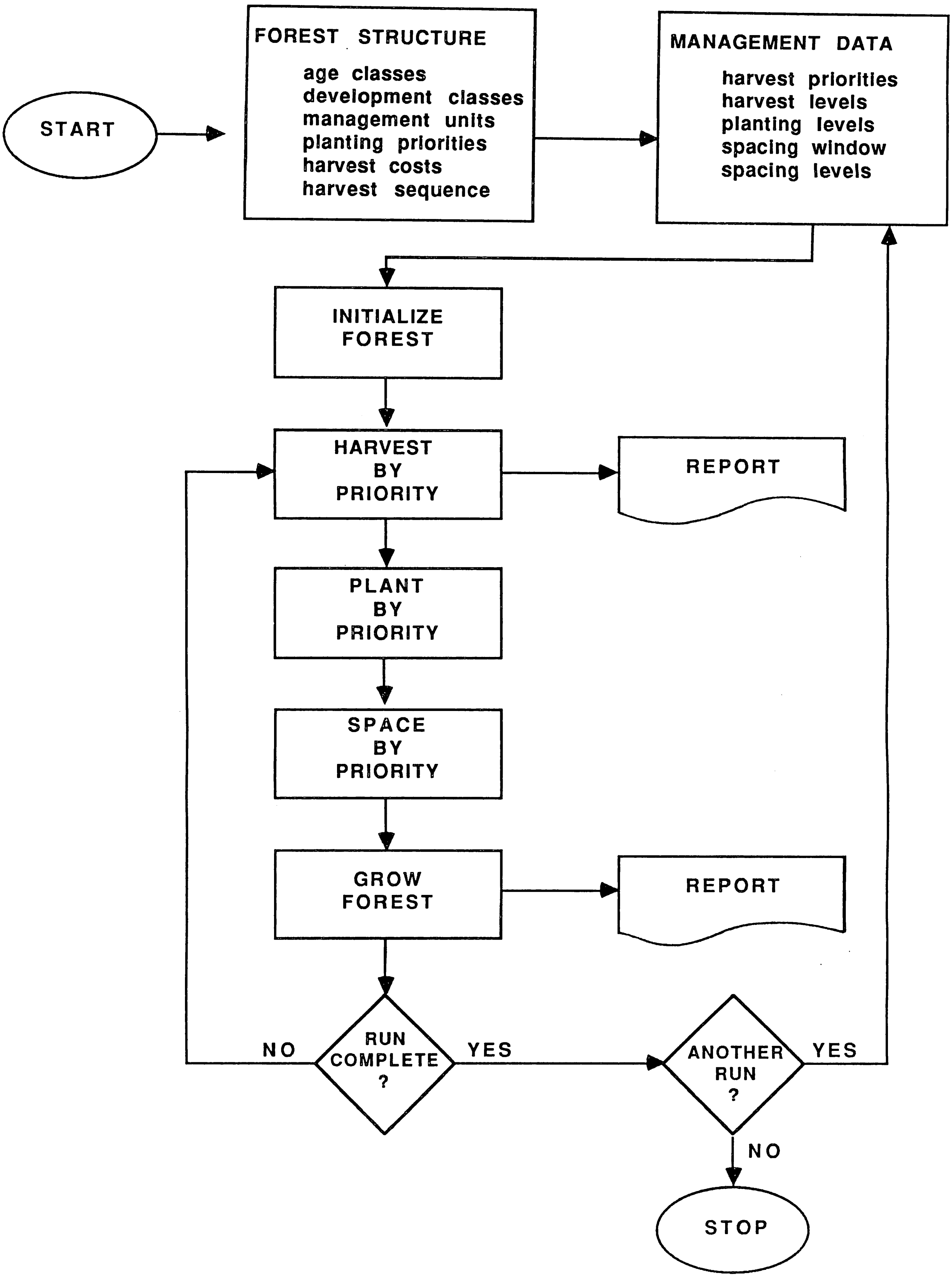

Figure 4. FORMAN structure

ments, harvests, and costs, and the final forest structure. Alternative management strategies (combinations of harvesting, planting, and spacing over time) may be readily designed and evaluated.

FORMAN allows users to investigate assumptions about stand development, treatments, treatment responses, and treatment-allocation rules. Relationships among treatments carried out within stands and the forest-level consequences of these treatments are illustrated. Note that FORMAN does not contain any growth equations. These must be supplied by users as time-dependent curves associated with particular treatment sequences, species, and sites. Users must specify at least a single-species volume development curve for each treatment regime/species/site combination of interest. These curves may be broad averages, such as those found in Plonski (1981), or they may be developed from a local version of a stand-level modeling system such as STEMS. In any case, the capacity to address forest investment questions with FORMAN is limited more by the availability of reliable treatment-response forecasts than by the basic structure of the modeling system.

Concluding Comments

Models provide quantitative tools for using data and information to design stand-level tactics and forest-level strategies. The biggest impediment to effective model use in support of forest investment decisions is not model availability. Many models and modeling systems are available, but often we do not have local data upon which to base accurate forecasts of the consequences of alternative stand-level investments. We must be able to forecast these consequences if we are to direct investment resources (such as dollars and planting stock) to our best sites. Data deficiencies are not easily overcome, because we can validate our stand-level forecasts only by comparing predicted and actual long-term growth responses, with the aid of Continuous Forest Inventory or Permanent Sample Plot data.

Changing product markets exacerbate these problems by making the forecasting of future product values difficult. This suggests that flexibility is a prime consideration in the design or choice of stand-level and forest-level models. We need models that can forecast the consequences of many treatment alternatives for many species. Forecasts of indicators such as gross and net merchantable volume must be supplemented by forecasts of indicators such as sawlog/pulpwood distributions over age and internal rates of return. The STEMS system has potential for meeting this need in Ontario. The basic forecasting tools must be complemented with means of assigning economic values, such as treatment costs and product prices, to the various treatment regimes. If we have the economic data, QUICK-SILVER can make the necessary discounting adjustments to reflect the timing of expenditures and the realization of revenues.

With a set of stand-level tactics, we need forest-level modeling systems that can help us design strategies with the flexibility to respond to evolving markets, while promising reasonable economic returns. We must seek strategies that offer good returns over a range of market conditions. Simply restocking all cutovers to pulpwood standards, because this is a cost-effective tactic for meeting government reforestation requirements, may turn out to be myopic. Transparent and easily used inventory-projection modeling systems, such as FORMAN, allow users to explore many alternative assumptions about the future, in terms of both stand-level treatment responses and forest-level market conditions and product requirements.

ACKNOWLEDGMENTS

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SESSION II: Optimal Harvesting

ORGANIZATION OF THE FOREST -- A MANAGEMENT PLANNING PERSPECTIVE

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Abstract--Constraints on effective planning in the context of industrial forest management are discussed, with emphasis on those elements of the planning enterprise that indicate shortfalls associated with the planning process as it is constituted at present.

Résumé--Cet article traite des contraintes à la planification efficace dans le contexte de la gestion forestière industrielle. Il met l'accent sur les éléments de l'entreprise de planification qui font ressortir les lacunes du processus de planification tel qu'il existe à l'heure actuelle.

I am not much good at jokes and have great admiration for those speakers who can introduce their topic with a pertinent and humorous anecdote. However, I do think that I have a way with parables. Mr. Webster tells me that a parable is a short story that carries a clear moral. Accordingly, I shall share with you an ancient parable that focuses, to a degree anyway, upon the topic that has been assigned to me: "Organization of the Forest--A Management Planning Perspective".

Before getting into my parable I might say, however, that the views expressed in this presentation are representative of my own opinions as an industrial forester, and do not necessarily reflect those held by members of the forest industry as a whole in this province.

There once was, in an ancient land, a landlord who had a house. It was a sturdy dwelling--well appointed and commodious. He rented this house to a citizen of the land--an honest and diligent tenant who kept the dwelling in a tidy condition and paid his rent in a timely manner. It came to pass one day that the landlord went to the tenant and said, "I have noticed that thou art a fine tenant and maintain my house properly. Accordingly, I wish thee to accept into thy household my weaver of cloth and my maker of pots. Thou shalt make these people comfortable in thy household at no cost to them." The tenant implored: "My lord, I have little room remaining and cannot afford more people in my household." The landlord responded: "Hast thou no social conscience? Surely thou shalt find a way." And by prudent and judicious management the tenant was able to cope with the added burden to his household. And it came to pass again that the landlord went to the tenant and said, "Thou hast done admirably with my weaver and potter. They tell me that the lodgings are clean and the nourishment is wholesome. They are very satisfied in your household. I regret to say, however, that I must increase thy rent." "But my lord," replied the tenant, "Thou hast already increased my living expenses and caused hardship for my household. I cannot endure further privation. This is the straw that breaks the camel's back."

"Hast thou no social conscience? Surely thou shalt find a way," answered the landlord. And lo and behold the tenant found a way. He moved his own household into a dwelling in the next valley. It was a sturdy house--well appointed and commodious. The conditions of tenancy were fair. The tenant prospered and his household was happy. And it came to pass that one day the tenant and the landlord met in the village market square. "How art thou doing?" asked the landlord. "Very well indeed," replied the tenant. "The dates are abundant; the grass is sweet and the sheep are fat. My household is prosperous and happy. And how about thee?" "Well," said the landlord, "I have been unable to rent your former habitation. The weaver and potter still occupy the premises. They will not leave and refuse to pay rent. Strangely, whenever I tell them that they must vacate the dwelling they say, "Hast thou no social conscience? Surely thou shalt find a way." I am still trying to find a way."

Well, what is it that we have learned from this ancient parable? What are the salient messages that the parable is attempting to convey?

It seems to me, as an industrial forester, that the parable illustrates a couple of interesting and related points that are noteworthy, particularly when viewed in the context of sound and rational planning for management of the forest resource.

First, there is a clear message that arbitrary rearrangements of the landlord-tenant relationship will in all likelihood cause a major degree of hardship to the principals involved, and may result, at their worst extreme, in enduring and irreversible damage to the relationship. I call this the "tinker" principle.

The second message demonstrates the real danger of attempting to accommodate the needs of one tenant group at the expense of another tenant group. This, in my view, indicates a significant breach of the landlord-tenant relationship, and violates the rule that the user pay in proportion to the benefits he derives. I call this the "free lunch" syndrome. So now we have it, concisely and succinctly: the "tinker" principle and the "free lunch" syndrome, which collectively represent the major obstacles to a rational approach to planning in the context of the process as it exists at present. A very large proportion of the wood fiber required to sustain the forest products industry in Ontario is derived from crown land. Crown land is owned by the citizens of Ontario, with stewardship and custodial responsibility mandated by statute to the Ontario Ministry of Natural Resources (OMNR).

Inasmuch as crown land in this province is a publicly owned resource, there is a wide community of interest that has to be recognized in terms of relative apportionment of forest benefits. Some of these benefits are tangible and measurable; others are abstract and difficult to quantify.

"The greatest good to the greatest number" is indeed a lofty ideal, and has a beautiful political ring to it. Simple. Benevolent. Democratic. In reality, however, the exercise of "rationalizing" the diversity of forest-user requirements requires great skill and patience to ensure that all the bases have been covered.

The government of Ontario has developed the Timber Management Planning Process as a tool for harmonizing and guiding forest management activity on crown lands in the province. Public participation in the planning process is the means; an integrated approach to resource management is the objective.

In theory, this sounds great. What could be better than a "democratized" approach to forest management? Everyone who has some interest in the forest is involved in the decision-making process. All entitlements to benefits are shared on a relative basis.

Utopia! **Almost**, but unfortunately, not quite. The basic ingredients in any planning recipe are:

(1) purpose and objective

(2) ability to attain objective

(3) ability to measure goals

(4) accountability.

At this point I shall attempt to provide a critique of the Timber Management Planning Process from the view of those essential elements in the planning equation, and in the context of what I perceive as impediments to rational planning so as to achieve industrial timber management objectives.

Obviously, time does not allow me to be detailed or very precise. I shall, therefore, share what I consider to be the factors that militate against a market-driven approach to timber management planning.

Purpose and Objective

Earlier I mentioned public involvement in goal setting and referred to what is probably the principal government objective of the Timber Management Process, namely, that benefits accrue to all citizens of Ontario. In an attempt to focus this objective, OMNR has opted to incorporate these benefits into an overall objective of integrated resource management. This objective presupposes that all forest values can, in spatial and temporal terms, be shared by all who carry on some activity in the forest. Unfortunately, life is not quite that simple.

The element that perplexes me the most about the present timber management planning exercise is the absence of a practicable economic framework within which reasonable decisions about land use can be made on an integrated basis. Maybe to some degree this is due to a lack of both appropriate biological data and knowledge of the various data bases related to timber management. However, I am inclined to think otherwise.

I believe that the lack of economic or financial direction is a direct result of conditions imposed by the Environmental Assessment Act. All vestiges of cost-effective forest management seem to have been "tinkered" out of the system in order to ensure that all client groups are allowed to exert their influence on the planning exercise.

The three assurances that the forest industry in Ontario needs to maintain a reasonable market share are:

(1) security of tenure to protect large investments in capital and plant

(2) security of the land-base within a practicable tenure arrangement to ensure long-term wood supply to mills

(3) wood flow to millgate at a competitive cost.

If the integrity of any of these requirements is threatened through some application of the "tinker" principle, members of the forest industry view this with great concern and alarm. I believe that they derive some comfort from the idea of long-term tenure under the Forest Management Agreements (FMAs). The tenant-landlord relationship is to a degree secured on a contractual basis through the judicial process, and is therefore somewhat "buffered" from the vagaries of the political system.

The erosion of the productive forest land base with its attendant problems of incremental cost involved in managing for uses other than that of timber production is a major concern in the forest industry. The resulting financial impact is measurable in terms of the cost of delivered wood at the millgate.

The forest industry is perhaps the largest stakeholder in the timber management planning process, and without a doubt is the largest contributor of taxation revenue to all levels of government. It is on this basis alone that more equitable economic and financial criteria should be applied to the process of establishing useful and practicable objectives. It is important that the **economic** environment be as well protected as the biological and social environments. The economic realities must bear considerably more weight and substance in the hierarchy of decision making about land use in order that practicable and attainable forest management goals may be set.

Ability to Attain Objective

This is the second module of the planning enterprise that we shall put to the test.

If indeed we recognize shortcomings in our objective, then our ability to attain that objective will be called into question.

Nevertheless, there is a timber management planning process in effect, imperfect though it may be, and the principle of attaining an objective does have its place in the scheme of things.

The timber management planning process, public consultation and government review, involve development of a plan of action to cover all activity in a forest area for a 20-year period.

The document that results is the Timber Management Plan (TMP). An integral part of the TMP is an operating plan that details precisely what is expected to be done during the first 5-year period of the TMP. There is also a "roll-over" clause in the TMP for renewal and adjustment at five-year intervals.

The operating plan includes infrastructure development, harvest allocation, forest renewal and tending, and attempts to take into account the possible effects of timber harvest on other uses of the forest.

At this point it should be noted that the TMP is developed on the assumption that the forest industry, by virtue of its tenancy relationship with the crown, will recover the cost of road construction and silvicultural activity. Any significant departure from this tacit rule makes it extremely difficult to achieve objectives. Any attempt to prevent cost recovery or increase forest taxation has an enormous ripple effect throughout the entire planning process. There is, however, a mechanism built into the process that is supposed to obviate the difficulties associated with deviations from planned objectives. This is called the amendment process. All deviations from the original plan must be supported by a major or minor amendment, depending on the degree of departure from planned objectives. In most cases public participation is required, and it is a costly, time-consuming and cumbersome arrangement, but one with which the forest industry has learned to live.

Inasmuch as the establishment of proper timber management goals and objectives is not sensitive to market forces, and assurances for reasonable cost recovery are diminishing, it will become increasingly difficult to achieve the objectives of the TMP. There is not enough flexibility in the planning process to allow for sound and practicable contingency planning.

If we acknowledge that the "tinker" principle will continue to chip away at our expectations of reasonable profit, my worst fear is that the original plan will bear no resemblance to the TMP developed through the amendment process, and this brings me to my next point.

Ability to Measure Goals

What the planning process lacks in terms of purpose and ability to attain objectives is certainly compensated for by the ability to measure goals. Here is a classic case of "overkill".

Every facet of the TMP, once it has been established and approved, is under the microscope.

Compliance with planned objectives is paramount, and deviation is measured resolutely from every conceivable angle. Proposed variations to the TMP, as I explained earlier, must be handled through the amendment process.

In addition to the restrictions placed on departures from planned objectives, and the associated difficulties resulting from the amendment process, all forest industry activity is subject to an enormous number of regulations, guidelines, policies, and directives. Each is separate and distinct, and each assigns its own penalties for non-compliance. The system is very definitely over-regulated and punitive in its approach.

The custodial responsibility of a public resource requires that the landlord manage or control by edict and decree, and administer some kind of penalty for violation of the rules. This is understandable, but I wonder if we are using impracticable and unattainable benchmarks for measuring such violations? Maybe we are umpiring a cricket game on the basis of a baseball rule book.

Excessive time and energy spent in this area may be counter-productive. It would be better, perhaps, to redesign the elements of the planning process that are obviously weak.

Accountability

Preparation of the TMP is undertaken on a group basis. Because the TMP deals with a public resource and will ostensibly address all the concerns of those who will benefit from crown lands, public participation is the **key** element in the planning process.

The manner in which timber management activity is planned is described in great detail in the Timber Management Planning Manual, and is structured so as to include all who are involved in deciding the direction or organization of the forest resource.

The team approach to planning is used in the development of the TMP: all stakeholders are allowed to exercise their influence, directly or indirectly, in its preparation. The planning team comprises both task and technical committees, whose members are collectively responsible for putting together a plan that conforms exactly with rules set out in the Timber Management Planning Manual. There is public involvement in the entire process and high-level government approval is required to formalize a TMP. There are a great number of "fingerprints" on the final planning document, but nowhere is there individual accountability in the TMP itself. Management planning by committee, through group decision making, makes it virtually impossible to assign individual or even collective accountability. No one is accountable for the TMP. However, **all** is not lost. The TMP is **very** much accountable to, of all things, the **process** itself. It is accountable to that great inanimate collection of rules, regulations, policies, guidelines, approvals and so on.

No individual or collection of individuals can be chastised for putting together a bad TMP, provided that obligations to the Timber Management Planning Manual have been met, and targets for completion of various phases of TMP development have been reached. And, of course, the TMP must have received the proper approvals and authorizations up to top levels of OMNR.

So, what do we have? My evaluation of the essential elements of the timber management planning process looks something like this:

1) purpose and objective: lacking in economic context

2) ability to obtain objective: suspect

3) ability to measure goals: overkill

4) accountability: only to the process.

"Forest Investment: A Critical Look" is the central theme of this symposium. The instructions that I received from the organizing committee were to present a paper that would undertake to view problems with and constraints on proper forest investment in a critical and thought-provoking manner. I hope that I have accomplished this.

I have not come here with the sole purpose of delivering a stinging indictment of the current planning process. I do believe that in my short presentation I have, to a degree, addressed some of the elements that impede sound and practicable approaches to planning for industrial forestry purposes.

I might add that the shortcomings in the planning enterprise upon which I have touched are institutional by nature, and can be overcome mainly by working through the political process. There must be political purpose and commitment to ensure the economic well being of an important sector of Ontario's economy.

The tenant can only advise; it is for the landlord to decide.

In conclusion, I shall summarize what I perceive to be the principal impediments to good planning and offer some suggestions for resolving problems.

1) Data on land-use relationships are required to ensure proportional cost:benefit parameters. Equitable "user-pay" systems must be developed so that costs are divided proportionately. The landlord-tenant relationship must be carefully appraised, particularly in the context of the FMAs. Significant effort should be made to mitigate the "free-lunch" syndrome.

2) The assumption underlying the planning process is that timber management objectives will be attained if the landlord underwrites development and silviculture investment costs to a reasonable degree. It is essential that the integrity of this principle not be violated. Any degree of "tinkering" will have a negative effect on all elements of the planning process, and both chaos and a lack of direction will result.

3) There is a decided lack of economic framework in the planning process. This manifests itself in land-use decision making not only at the development stage but throughout the planning process. A great deal more attention must be given to cost:benefit analysis in making land-use decisions, and to the realities of the marketplace. These realities must be reflected in the planning process through the application of sound financial and economic analysis and reasonable market appraisal techniques. Without clever economic and financial direction the TMP will be regarded as a quasi-political tool.

I started my presentation with a simple parable. I suppose that it is not easy to be a landlord. Similarly, it is not easy to be a tenant. I can only hope that the landlord in his wisdom will indeed be able to find a better way.

THE EFFECTS OF AGE CLASSES, ROADS, AND WOOD QUALITY ON HARVESTING

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Abstract--This paper deals with the problems of harvesting the existing forest. Age-class structure, species mix, tree size (length and diameter), branchiness, stocking, and terrain are some of the variables that affect safety, productivity, and cost of harvesting.

Résumé--Les problèmes associés à la récolte de la forêt existante sont examinés. La répartition des classes d'âge, la composition de la forêt, les dimensions des arbres (longueur et diamètre), l'importance des branches, la densité de peuplement et le terrain sont quelques-unes des variables qui influent sur la sécurité, la productivité et les coûts de la récolte.

INTRODUCTION

The overriding problem in harvesting the existing forest lies in the fact that the quality of the available forest is deteriorating. Areas with excellent timber are still to be found, but most forest companies are being forced to harvest forests of poorer quality than those they have harvested in the past.

The quality of fiber in each tree has not changed, but the quality of available stands is declining. Age-class structure, species mix, tree size, branchiness, and stocking are some of the factors that affect the cost of harvesting. Terrain, road standards and environmental constraints such as concern about fish and wildlife must also be taken into consideration.

Age-class Structure

Since the inception of Forest Management Agreements (FMAs) and the outbreak of the spruce budworm epidemic in northern Ontario, forest companies have been meeting a greater portion of their volume requirements in overmature, multiple-age stands. Their objectives have been to harvest overmature stands as quickly as possible so as to release land for regeneration purposes and more rapid growth, to salvage as much damaged wood as possible before it becomes useless, and to remove susceptible stands and reduce the overall vulnerability of the forest in the event of another budworm infestation.

Harvesting problems are numerous in overmature, multiple-aged stands. Tree ages in these stands can vary from 30 to 40 years in the understorey to 140 years in the overstorey. This creates a significant variation in both tree length and diameter, and hence in volume. The understorey usually consists of balsam fir (**Abies balsamea** [L.] Mill.), black spruce (**Picea mariana** [Mill.] B.S.P.) and white spruce (**P. glauca** [Moench] Voss), and the overstorey consists largely of white spruce. Such stands have a lower yield per hectare than do even-aged, mature, homogeneous stands because many of the original trees have been windthrown or are decayed and show up as culls in harvested wood.

Tree Size

Variation in tree size is probably the most significant factor affecting harvesting costs in multiple-aged stands. The smaller the tree, the higher the cost of harvesting (Morrison 1980). The handling procedure in the harvesting process is generally the same for a small tree as it is for a large one, regardless of harvesting method (Modney and Rotherham 1988). A smaller yield therefore means a higher cost per tree. Harvesting cost per tree is thus inversely proportional to tree volume. For example, if a delimber were to take 30 seconds to delimb a 6-m balsam fir tree from the understorey and the same time to delimb a 20-m white spruce from the overstorey, the volume of wood would be significantly higher and the harvesting cost significantly lower in the case of the white spruce. Thus, the cost per m^3 is reduced as tree size increases. If stands were more uniform, however, machinery designed to handle trees of a particular size could be used more effectively. It is probable, too, that the difference in the relative cost of large- and small-tree harvesting could be reduced.

Species Mix

The species mixture that is common to overmature forests can also contribute to the cost of harvesting. A variety of products is created from this type of stand. The larger-diameter white spruce makes excellent sawlog material whereas the smaller-diameter black spruce, white spruce and balsam fir provide excellent fiber for pulp and paper. Hardwood species such as birch (**Betula** spp.) and poplar (**Populus** spp.) are used for veneer, waferboard and kraft pulp, but are much more susceptible to market fluctuations.

Unfortunately, some pulp mills have a problem handling mixed quantities of balsam fir and spruce, depending on their end product and manufacturing process. In some cases, it is necessary to sort the species in order to produce paper of superior quality. Therefore, an additional cost is incurred by woodlands operators who are required to sort when harvesting in mixed stands of spruce and balsam fir. In stands in which species mix is not a significant problem, harvesting is simpler and, therefore, more efficient and less expensive.

Branchiness

Branchiness is another variable that has a significant effect on safety, productivity, and the cost of harvesting. Branchiness is a prominent feature of the overmature, uneven-aged stand. Because of the open-growing, low-stocked nature of this type of forest, crown closure in most cases does not occur, particularly among overstorey trees. This gives each tree room to spread its branches.

As forest companies encountered overmature, multiple-age stands with greater frequency, harvesting methods began to change. Conventional cut- and-skid operations led to a decrease in productivity because of branchiness and tree size. Harvesting in overmature stands containing large numbers of dead or broken trees on the forest floor and dead standing trees (chicots) led to increased safety hazards for cut-and-skid workers. Saw kickbacks, trips, falls, and eye wounds are examples of the injuries directly attributable to limbing of this type of tree by conventional means.

As harvesting operations shifted to older stands, mechanization began to develop at a rapid pace. Tree branchiness was probably the most significant factor leading to the increased use of mechanical delimbers.

The costs incurred for accident compensation and sick leave benefits are now tipping the scale in favor of mechanical logging. There is less risk to the employee on mechanical operations and a smaller work force is required, both of which factors reduce the probability of accidents. Cut and skid can still be a very economical and versatile harvesting method; however, when the probability of accidents is considered, mechanical harvesting begins to look more attractive to the cost-conscious forest manager.

Despite the increasing use of mechanical harvesters, branchiness is still a significant factor affecting productivity. Delimbing and grapple skidding are two aspects of mechanical harvesting that are greatly affected by branchiness. The larger the trees and the greater the number of branches, the more wear and tear there is on delimbers, the higher the fuel consumption, the lower the productivity, and the greater the skidding resistance (as a result of the weight of and drag from branches) for skidding to roadside.

Stocking and Density in Relation to Road Costs

Stocking, which has a direct effect on yield per hectare, is generally low in overmature, multiple-aged stands. Road costs have a significant effect on the cost of harvesting. Low density means low volumes per unit area. Low volumes per unit area require more road to gain access to a specified volume and, hence, costs are higher per unit of volume.

Terrain

Terrain is a very important variable that affects cost, productivity, and safety of harvesting. Terrain also has a significant effect on road building. Rough terrain generally requires more expensive roads and, subsequently, leads to increased harvesting costs.

Terrain is also a critical factor in the harvesting operation, regardless of the harvesting method. Rough terrain is hard on machines, whether they be skidders, feller bunchers, or feller forwarders. Terrain has a direct effect on the productivity of harvesting machinery. It is more difficult for machinery to maneuver when slope and the incidence of boulders and rock outcrops are increased. Safety is also a more important factor as terrain becomes rougher. For example, machines roll over more frequently on rougher terrain.

Although there is no proven correlation between rough terrain and overmature, multiple-aged stands, these features occur simultaneously with more frequency in the existing forest. Neither feature was attractive to loggers in the past, with their limited access to mechanized equipment, and consequently, both were generally avoided. Rough terrain and multiple-aged stands with low yield per hectare increase harvesting costs.

Road Access

Another problem associated with harvesting of the existing forest is that road access is essential if subsequent forest renewal activities are to be undertaken. The quality of the extraction road is being upgraded to facilitate access for purposes of forest renewal at a later date.

Backhoes are being used in the construction of camp extraction roads. The backhoe provides excellent subgrade material while creating less disturbance than bulldozers. Subgrade material comes entirely from the road right-of-way. The borrow areas serve to drain the subgrade material very effectively, reducing the amount of gravel surfacing required. Culverts are located in appropriate places, thereby ensuring future access for renewal activities. In the past, these roads were built to minimum standards, solely for the purpose of extracting the wood. The improved quality and consequent higher cost of extraction road are therefore increasing the total cost of harvesting; however, a reliable road-access network is essential to any integrated forest management program.

Environmental Constraints

Harvest planning in the existing forest has been complex. The forest is managed according to the multiple-use concept. Fish and wildlife and recreational concerns are of paramount importance. All annual, 5-year and 20-year company management plans make provision for the concerns of all forest users.

Environmental constraints are increasing harvesting costs because the location of roads must be changed and higher standards of road construction are required. Considerable time is devoted to the planning and harvesting phases of forestry operations to ensure that all environmental requirements are met.

Integration of Harvesting and Forest Renewal

One other major problem connected with harvesting today is the fact that harvesting and forest renewal in Ontario are more closely integrated than ever before. Prior to the inception of the FMAs in 1980, harvesting and silviculture had little in common. Forest companies undertook the harvesting, and the Ontario Ministry of Natural Resources conducted the silvicultural activities. Each attempted to improve the efficiency of its operations, but both functions are so closely related that integration was necessary. Fish and wildlife and other environmental concerns are now incorporated into the planning of both harvesting and renewal operations.

It is wise to plan both activities simultaneously. Harvesting and forest renewal are now being undertaken by the same people in some cases, and this permits greater continuity of operations. A working knowledge of the harvest area is of great benefit during the renewal process. Road access networks are now being planned with forest renewal and other considerations in mind, not just harvesting.

The benefits of integration have been numerous, but perhaps there is still room for improvement. In some cases, modification of the harvesting method can ensure better results, particularly when one is dealing with natural regeneration. The scheduling of harvesting and scarification can be crucial when natural regeneration is employed, especially in the case of jack pine (**Pinus banksiana** Lamb.). The harvest prescription is generally the first step in the regeneration process.

Pre-cut inspections to determine existing regeneration levels are needed to establish the best harvesting system for each site (Ruel 1988). The harvesting and renewal prescription can be varied to ensure that the desired future crop is established effectively. In Ontario, the concept of integration of harvesting and silviculture is still in the development stage.

CONCLUSION

Most forest companies in Ontario will not be harvesting plantations on a large scale for at least 40 to 50 years. The problems connected with harvesting the existing forest will be with us for many years to come. It is essential that the current fiber supply be harvested efficiently to make the best use of its potential and to minimize the "regeneration gap".

Under the present policy of cutting the oldest stands first, can we be sure that volume is not being lost? Industry is currently building roads past or through mature spruce and pine stands to get at overmature stands that have become decadent and have only a fraction of the volume per hectare of stands bypassed on the way to older stands. While we are harvesting the older stands, which some argue are in an overall state of equilibrium (i.e., they are not likely to deteriorate further) the mature stands are deteriorating, and we are losing an opportunity. Research into stand dynamics is needed to permit us to make the best use of what we have and to meet our targets.

Currently, mean annual depletions are calculated for working groups, but working groups usually include a variety of species with different growth characteristics. Rotation ages of these species differ, but calculations are based on the predominant species. Are we losing potential volume by allowing mixed stands of spruce, pine and poplar to grow until they reach the greater rotation age of spruce? Do we really know? Perhaps this is another area in which research would be useful.

Recently there has been a trend in this province towards more natural and less expensive regeneration. Can our future fiber requirements be met by natural stands? Natural stands will yield less fiber and take longer to reach a particular stand volume than managed, "man-made" stands. More research into growth and yield is urgently required.

Predictions of yield from plantations and naturally regenerated stands vary considerably. An opportunity awaits us to manage our existing stands by employing yield-sensitive planning and operations. If the knowledge is available and if we do the job right, the existing forest will yield higher volumes of better quality wood than if we continue to operate under current rules or rotation-age selection and priority harvesting. Any returns we realize will prolong the period before the effects of shortages are felt, will help us to control harvesting and renewal costs, and will improve our competitive position in world markets. On the basis of reported yields from other provinces, most future yield objectives are attainable, and our challenge is to meet these objectives.

An enormous commitment will be required from all foresters in the province to ensure that the handicaps currently connected with harvesting the existing forest are minimized in the future. For most of us in the industry that means over the next 40 to 50 years.

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CREATING A FOREST THAT'S AN ASSET: A HARVESTING PERSPECTIVE

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Abstract.--Several concepts around which crop plans for Ontario's future forests are being designed are seriously flawed, and the resulting forests will impair subsequent logging, hauling and processing operations. Neither large trees nor extensive monocultures are required. From a harvesting perspective, stand densities that capture the site's yield quickly in a medium-sized tree represent a practical compromise that will minimize total costs. In a region with relatively slow growth rates, a strategy with a minimal cost objective may be the most effective.

Résumé.--Plusieurs des principes sur lesquels s'appuient les plans d'exploitation des futures forêts de l'Ontario risquent de provoquer des résultats peu satisfaisants. En effet, les plans d'exploitation aujourd'hui en vigueur donneront des forêts qui se prêteront mal aux futures opérations de coupe, de transport et de transformation. On n'a besoin ni de gros arbres, ni d'une monoculture extensive. Du point de vue de la récolte, une densité de peuplement qui permet d'exploiter un site rapidement avec des arbres de taille moyenne représente un compromis acceptable qui réduit les coûts totaux au minimum. Dans une région où les taux de croissance sont relativement faibles, une stratégie maintenant les coûts au minimum pourrait être la meilleure.

INTRODUCTION

It is generally assumed that any crop plan that produces larger, straighter, healthier, better formed and defect-free trees, and stands with higher yields per area, will be desirable from the perspective of loggers and haulers. However, other factors also affect logging and hauling operations. Crop plans that do not take this into consideration will inevitably result in forests that are less valuable than they could have been.

This paper looks at crop planning in Ontario's boreal forest from a logger's and hauler's perspective. Its intent is to show:

1) why the end result of our present crop plans will not be an asset

2) how the risks of intensive forest management can be minimized

3) where our efforts should be directed to maximize the potential economic benefits from our silvicultural expenditures.

I shall argue that a medium-sized tree offers the most potential for maximizing returns, and that crop plans that keep trees growing vigorously and as long as possible offer the least risk.

Crop planning must be an economically based activity. Only stands and forests that are more valuable than those nature produces by itself will justify the silvicultural cost of producing them.

TREE CHARACTERISTICS

Many of our crop planners believe that they know and understand what loggers, haulers and mills want from the stands they are designing. Indeed, the requirements for tree characteristics such as stem straightness, freedom from defect, and branching habit are well understood. Unfortunately, other characteristics are being affected by these crop plans in ways that may hinder future harvesting, delivery and processing operations.

Taller or Bigger?

Most of our crop plans and tree improvement programs are aimed at taller, straighter trees with small branches and higher yields per area. Certainly, these benefits have been used to rationalize more expenditures on silviculture. And there should be little doubt that these aims can be achieved through stand prescriptions and manipulation of the basic growing stock.

However, planting approximately 2200 trees/ha, the single most common site prescription in Ontario, will not achieve these aims, especially when combined with natural regeneration stocking levels of 10-15%. With third-year survival rates of more than 85% now being achieved regularly in plantations, final stand densities will be very high. Scarification and aerial seeding of sites, the second most common prescription, will produce the same result.

These high stand densities have three major drawbacks:

1) Without subsequent treatments, future loggers and haulers will be stuck with the **fatal fifteens**, trees that are 15 m tall and 15 cm in DBH. (This "disease" is dangerous to the livelihood of camp foremen and woodlands managers.)

2) To increase tree size and to minimize losses due to mortality, multiple thinnings will be required.

3) Long rotations will be needed to achieve sufficient product dimensions and characteristics of value.

The end result will be either high harvesting costs or high stand establishment and management costs. Neither of these alternatives is particularly attractive.

Choosing dominant and codominant trees for our genetics programs, and making height the primary selection criterion, will only compound the problem. In a natural forest, height dominance and a large crown give a tree a relative advantage over its neighbors when it is competing for scarce supplies of light, water and nutrients. Tall trees probably require a large root system for support, and consequently, potentially valuable bole biomass is lost to the roots.

But neither height as such, nor a large crown, is desirable from a logger's perspective, and both are probably less important to survival in a managed stand. Early height growth is desirable for the sake of overcoming competing vegetation, but the idea that harvesting tall trees is preferable is misconceived. Several interrelated factors have led to this misconception.

Although some products require large trees, new logging, processing and manufacturing technologies have substantially reduced this

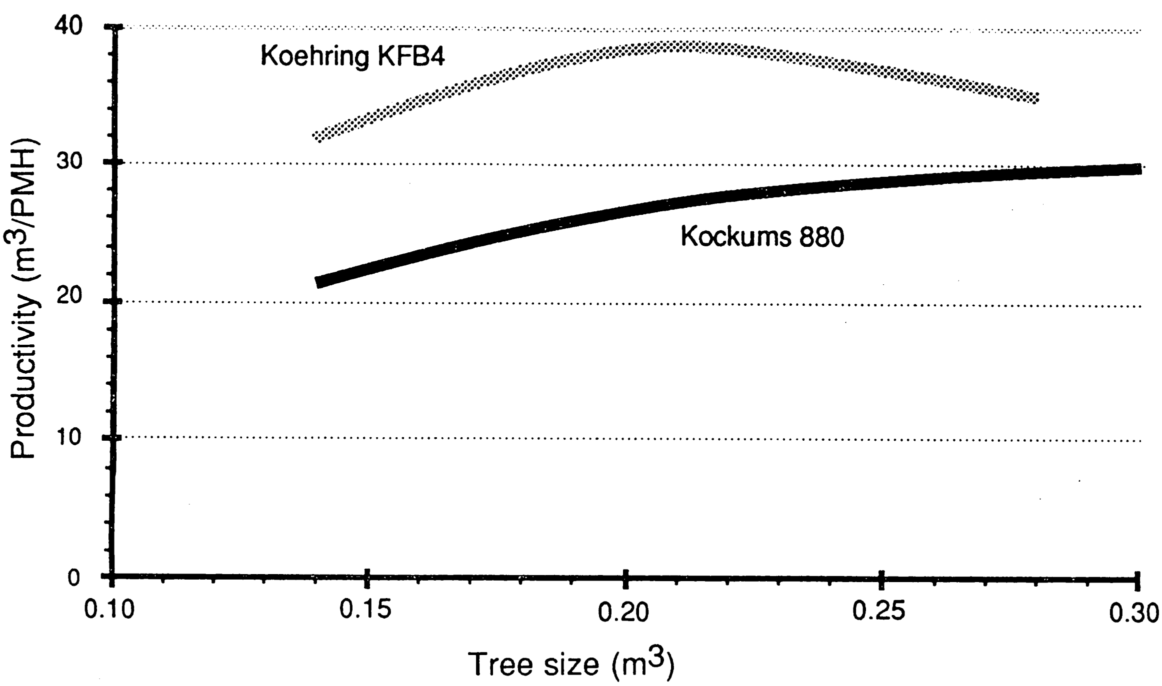

Figure 1. Productivity of two generations of wheeled feller-bunchers. The Kockums 880 Tree King has a single-stem, chain-saw felling head. The Koehring KFB4 has a multiple-stem, circular-saw head.

requirement. Both multiple-tree and circular-saw felling heads have decreased the impact of small trees on productivity and costs (Fig. 1). The ability to handle several small stems with a boom delimber has similar effects. Modern small-log sawmilling equipment can process logs at speeds 150-250% greater than is feasible with large logs. Often our basic technologies change more slowly than we want, but they still change much faster than tree or stand characteristics.

Logging costs are minimized at tree sizes that are smaller than is widely believed. This misconception is partly attributable to a generalization that is often made when production costs are being estimated. A typical time study of a logging machine generates an average cycle time per tree, i.e., the length of time it takes to cut a tree, on average. This cycle time is then converted into a production cost with an equation such as the following:

$$\text{Unit Cost} = \frac{\text{Cost/Machine Hour x Cycle Time/Tree}}{\text{Volume/Tree}}$$

This equation implies that an inverse relationship exists between tree size and unit cost. However, the cycle time per tree is not constant; it can vary substantially with tree size. The relationship is much more complex.

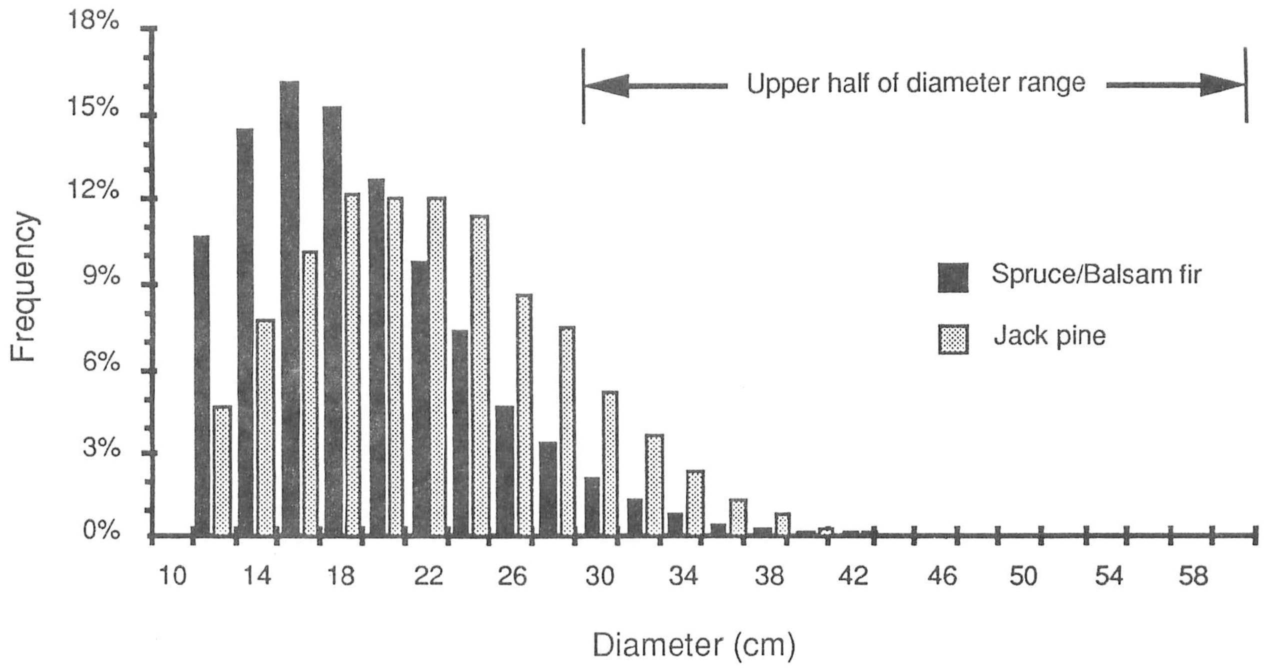

Figure 2. Typical frequency distribution of tree diameters in northwestern Ontario. About 11% of the stems occur in the upper half of the diameter range.

The link between tree size and production costs is further confused by the compromises in machine design that must be made if large trees are to be handled. In natural forest (Fig. 2), there are enough large trees that harvesting and processing machinery must be over-designed to handle them. Perhaps a third of a machine's size and a fifth of its weight are needed to handle the upper half of the range in tree diameters found in Ontario's forests. Crop plans and genetic programs that increase the trees' height will only compound this problem.

The need for mobility, particularly off-road, restricts machine size. Inevitably, design compromises must be made; small trees under-utilize the capacity of the machine, while large trees may exceed its capacity and lower its reliability. Over all, the need to harvest trees in a wide range of sizes probably increases direct harvesting costs (logging and transportation) by 10-15% in the boreal forest. This represents an amount about equal to the cost of establishing a new stand in Ontario.

Tree height can also affect hauling efficiencies adversely. For example, achieving legal loads with tree-length logs is difficult with the tree diameters most common in the boreal forest (Fig. 3). Tree-lengths of more than about 17 m cannot be legally hauled on the highway unless they have been bucked in the bush, and even then the overhang almost inevitably overloads the trailer's rear axles. As we gain better access to Ontario's forests, such imposed limits may restrict crop plans to a considerable degree.

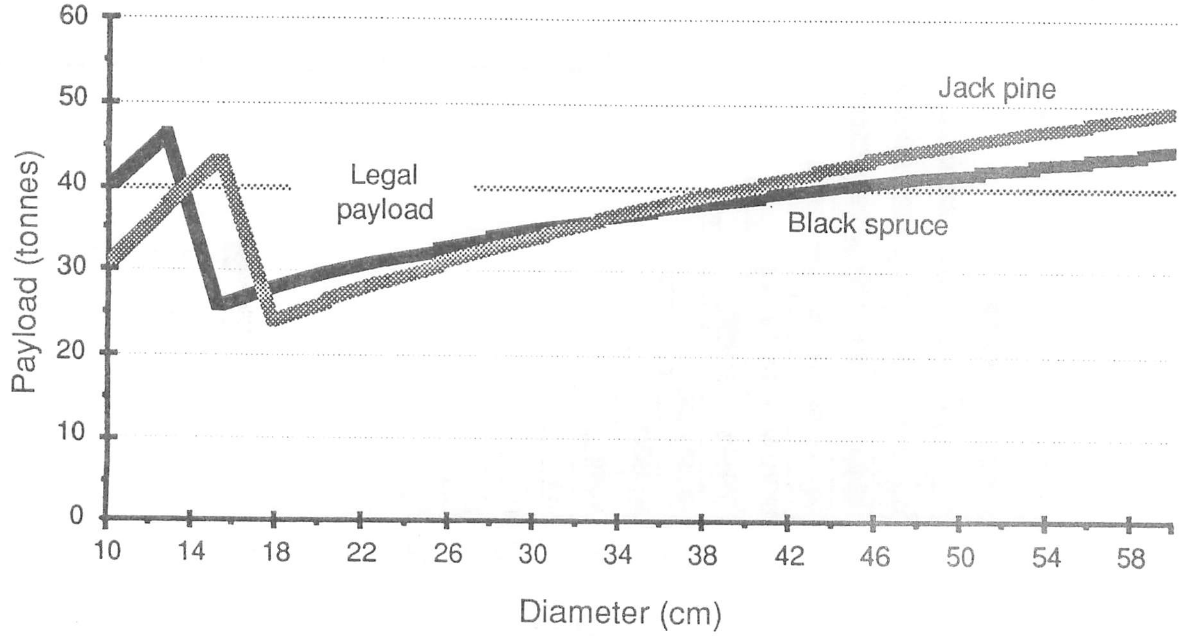

Figure 3. Effect of tree size on tree-length load size with a semi-trailer. The maximum legal payload of a flat-deck semi-trailer on Ontario highways is about 40 tonnes.

There is a particular danger in growing very tall trees since many small-diameter and/or short pieces may be produced from the tops. Processing and handling pieces shorter than about 8 m is very expensive--about equal to the present cost of stand establishment. The alternative, which is to waste some stem biomass, seems undesirable. Unless trees are at least 30 m in height, there is probably little advantage in growing trees taller than 20-22 m. The value of money tied up for the extra years needed to achieve such heights makes very tall trees an unattractive investment.

In Ontario, little harvesting has occurred in homogeneous managed stands. Hence, it is understandable that misconceptions about the importance of tree size have arisen. Over all, the harvesting cost curve in managed stands is much flatter than experience with past and present operations indicates (Fig. 4). Once the point of inflection on the production cost curve has been reached, little is gained by growing much bigger trees. Greater tree height is no panacea. Crop planners must remember that bole size is a function of height and diameter squared, and that a stem grows radially throughout its life.

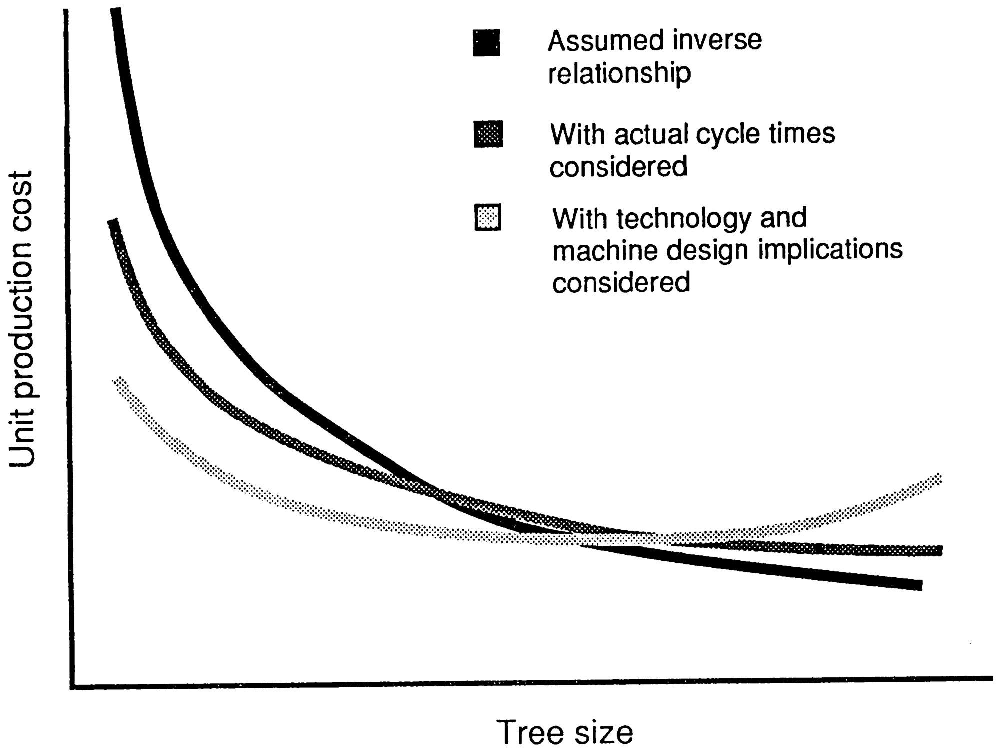

Figure 4. Production cost as a function of tree size.

Bark Thickness

Since bark makes up 10-18% of a bole's biomass, hauling bark represents a very significant cost with the long transport distances common in Ontario. Increasing average tree diameter would lower this cost because bark content varies inversely with diameter. Anything that reduces bark thickness or weakens the bond between the wood and the bark, without increasing the tree's susceptibility to insects and diseases, would be desirable to both haulers and processors.

Wood Density

The potential impact of changing wood density on pulp mill processes and lumber quality has received limited attention in Ontario. Most of this impact has been from the perspective of genetic manipulation of growth rates, and its effect on the amounts of juvenile wood. But crop plans could also enhance wood density. For example, increasing diameter growth could substantially reduce the proportion of juvenile wood in the stem, and thus raise average specific gravity. Since wood density varies in natural populations by over 10%, there is considerable potential for increasing wood density even without using biotechnology to manipulate the basic cell structures.

The impact of higher density for haulers would be significant. With highway hauls, a truck's capacity is fixed by both weight and volume (height, width and length) restrictions. Green wood is the only commonly hauled material for which legal limits on weight and volume occur so close together. Raising specific gravity would largely eliminate the volume limit on capacity; each load could be as heavy as legally allowed and the truck's center of gravity, a critical safety consideration, would be lower. Less variability in wood density would also help reduce truck overloading.

SPACING

The key questions for crop planners relate to spacing. Do we grow more usable wood per tree in a given rotation, or shorten the time to grow a given amount of wood per area? One quickly gains the impression that the objective in Ontario is the former, but our regeneration practices will lead to the latter. This inconsistency has occurred because many of Ontario's foresters believe that growing large trees will maximize the value of the province's forest resource. By growing large trees, crop planners have assumed that society benefits most from converting our forest into lumber.

However, the solid wood products industry in Ontario has not been profitable for years. Over the last two business cycles, only the pulp and paper industry has generated enough profit to cover the risks of economic activity. The harsh reality is that returns per volume of input on pulp and paper are 10 to 22 times those on solid wood products (Table 1).

With the relatively slow growth rates typical of most Ontario forests, the long rotations required for large trees are difficult to justify. Indeed, with present stumpage policies and rates for sawlogs, which in effect imply that a large tree (i.e., what sawmills want) is worth less than a small tree, crop plans with such aims cannot be justified.

The demand in the future will increasingly be for decorative wood products such as furniture and paneling, not the structural products into which most of Ontario's lumber now goes. However, our present crop plans will produce at best medium-sized spruce and jack pine, suitable only for the structural wood market. Yet only the decorative wood market offers any hope of providing an economic return for crop plans designed for lumber production. To grow the large-diameter logs preferred by sawmills, in view of the relatively slow growth rates typical of most Ontario forests, inherently demands wide spacings, long rotations and probably multiple entries into the stand.

Table 1. Profit margins per volume for various products.

	Stud lumber	Kraft pulp	Newsprint
Selling price	\$225/mfbm	\$945/t_{ad}	\$732/t_{ad}
- Distribution costs, \$/unit of sale	\$ 35	\$ 80	\$ 80
- By-product sales	100	5	
- Mill production costs	40	235	295
- Selling and administration	9	15	25
- Depreciation, interest and taxes	70	135	130
Total cost (mill to customer)[a]	54	460	530
- Logging costs, $\$/m^3$	14	14	14
- Roads and haul costs	19	19	19
- Overhead	7	7	7
- Stumpage	4	7	7
Total woodlands costs	44	47	47
Profit margin, $\$/m^3$	(\$13)	\$45	\$155

[a] Mill costs are based on a new competitive-scale mill with modern technology.

Stand Density

As mentioned earlier, logging and hauling costs reach a point at which increased size provides little additional benefit. Once trees reach this size, stand density is more important to loggers than tree size. Harvesting equipment can produce wood effectively in dense stands in part because non-productive travel is minimized, and smaller equipment can be used. Present crop plans certainly will ensure that dense stands are produced, but the small trees that inevitably result from such high stocking levels are definitely not what loggers and haulers want.

Establishing trees at wider spacings would reduce regeneration costs (e.g., fewer seedlings would be required per area), but tree form, branchiness, and juvenile wood percentages would suffer. Moreover, wide spacings require either machines with long boom reaches or those that move to each tree. Both approaches to machine design have inherent cost disadvantages. A long boom reach requires a large machine for the necessary support. Machines that move to each tree spend a large amount of time traveling (not cutting), and could cause extra site damage.

An indirect implication of tree spacing is that wider spacings also increase brushiness because more light reaches the forest floor. Such brush can delay harvester operators by 10-15% by blocking their visibility at a critical point during the felling cycle. If an environment is created that ensures and promotes the growth of competing species, wider spacing may also make subsequent stand establishment difficult, require another input into the crop plan (i.e., herbicide application) and retard tree growth.

Rotation Length

Much has been made of how the higher yields per area resulting from more intensive forest management could reduce hauling distances. Since hauling-related costs typically represent 35-50% of total wood production costs, the potential impact is significant. However, with the high stocking levels typical of present crop plans, these higher yields will be attributable largely to the fact that all potential sites are occupied.

Shorter rotation ages would also lower hauling distances, but our present crop plans are unlikely to achieve this. Many 10-year-old areas that were scarified and planted or seeded look just like fire-origin stands. Intra-tree competition will prompt a period of slow growth at early ages, and consequently extra time will be needed to reach specified sizes. Yet a 10-year reduction in rotation age would save haulers about two-thirds of present stand establishment costs. Providing enough space for stands to reach their potential final yield quickly is essential if substantially lower rotation ages are to be achieved.

Timing and Number of Entries

Crop planners and loggers will likely disagree about the timing of stand management activities. Experience has taught loggers to minimize the number of entries into a stand, the number of activities near the stump, and small trees. Yet the timing of a stand's treatment is often critical to the biological success of that treatment. This tends to require more entries.

There are tradeoffs between the benefits of treating a stand at the optimum time and the cost of doing the work then. For example, in areas without extensive road networks, entries to existing or new stands must be within 5-8 years of the final harvest date, or else high access costs (e.g., road construction and/or maintenance) will likely be incurred. Cutting small trees, particularly in tight conditions, is similarly expensive. This makes intensive thinning schedules impracticable in most of the boreal forest.

Ontario crop planners should not consider more than two stand entries: one when trees reach about 0.15-0.2 m^3 in size, and a final harvest when the trees reach about 0.3 m^3. Otherwise, the logging costs are simply prohibitive, and the returns too small.

The law of constant yield implies that the final yield per area is fixed and independent of stand density unless some constraint on growth is reduced. Thinning may capture some losses that are due to mortality, but focusing the growth capacity of a site on fewer stems inevitably underutilizes the site for some time. Hence, thinned stands produce somewhat less fiber per area than dense, but not overly dense, stands.

Our tree improvement programs may conflict with the law of constant yield. Individual stems may grow larger and/or faster, or have higher harvest indices, i.e., the proportion of the stand's total biomass actually recovered, but there is no guarantee that a stand's total biomass will change. Harvest indices are already high in even-aged, boreal softwood stands, typically 75%, so the potential yield increase in stem biomass is probably quite small.

Any further increase in biomass yield on fully stocked sites comes from either site or tree enhancement. Such an increase depends on whether and how much the constraints on growth can be practicably removed. Our growth rates, even in intensively managed stands, are such that the high cost of enhancing sites through drainage and fertilization and the value of money over time often negate any growth benefits. Consequently, crop plans must be designed so as to sustain yields without constant inputs.

Loggers can help accomplish this by not creating conditions that constrain growth. Harvesting practices that permanently remove the fertile upper soil horizons, e.g., for roads; disrupt water tables and drainage; shorten the growing season by compacting soils and driving frost into the ground; accelerate the oxidation of humus; and alienate the productive land base can all be largely eliminated at little cost with modern equipment and appropriate care.

Unless trees are better suited to the site, e.g., unless they are more drought-tolerant and less cold-sensitive, or unless their basic physiology is modified, e.g., by increasing its photosynthetic efficiency, the final yield per area is fixed. It is essential to identify and develop more suitable and more efficient trees, such as narrow-crowned phenotypes that can be planted at dense spacings; these are the hope for the midterm.

With existing stands and those that will be created in the near future, achieving some kind of spacing control quickly is essential. Many of our recently established stands need spacing now, but the treatment is difficult, often impossible, to justify. Stocking levels that will allow stands to develop until they reach a minimum acceptable size without extra inputs and entries can be achieved only when the stand is established. Our perspective must extend beyond seedling survival, meeting some questionable minimum stocking levels, and reaching the free-to-grow stage. The objective of managing forests must be to produce stands that are superior to what nature would have produced by itself.

STAND SIZE

It is widely believed in forestry circles that loggers want extensive monocultures. This mistaken impression has arisen because in natural stands with multiple products, e.g., sawlogs, veneer bolts and/or several species, separating the minor products reduces operational efficiency. The harvest index for minor products is often so low (< 10%) that they are very expensive to produce. Indeed, such products often would not be produced if their actual production costs were calculated, or if they were not very scarce.

There are those who argue that the value of some products may justify their production. But if product values are now that high, one wonders how much product substitution would occur if the end product bore its full production cost.

It is the amount of a product available within a stand that is important, not its area. With an appropriate crop plan, the stand is tailored to the product, so that both the harvest index and the yields of all products are sufficient to support efficient production.

It is also important to recognize that, in harvests of manmade forests, road costs are likely to be much lower than at present. Loggers who are reaccessing areas that were cut in the 1940s and 1950s will recognize that although road costs are not eliminated, pre-existing roads are definite benefits. Stand size will be less critical with managed stands and should not seriously constrain crop plans. As a rule of thumb, at least one complete truckload of each product should be permitted to accumulate within what would now be our optimal skidding distance.

The concept of a monoculture is more appropriate when applied to a "strip" of trees. For mechanical harvesting, the strip of homogeneous trees should be at least three times as wide as the swath width of a harvester, i.e., a minimum of about 40 m. This is a much smaller cutblock than is now generally considered practicable; it represents a bottom limit if the next strip to be cut is near. Narrower strip widths, particularly if strips must be left, would lower efficiency by hindering mobility within the strip and at landings.

The size of the overall area in which cutting takes place is still important in terms of its effects on how often the production unit must move, and the overall density of the road network. The minimum size is about a month's capacity of a production unit, e.g., a fleet of skidders, within about 2 km^2.

CONCLUSIONS

The objective of any crop plan designed for fiber production must be to produce that fiber economically. Historically, planners have tried to accomplish this by maximizing perceived asset value, usually by growing large trees.

Profit, the true measure of economic value, is the difference between production costs and selling prices. Lowering production costs can increase profit just as effectively as raising selling prices. Unfortunately, woodlands and mill production personnel have not ensured that the asset which crop planners are creating will maximize potential returns.

Large trees themselves seem unlikely to minimize total costs or maximize returns. Loggers and haulers want larger trees, but not necessarily taller ones. A tree of medium height with a larger diameter, cylindrical stem and little butt swell is probably the best compromise for silviculture, harvesting, transportation and processing. A final size of about 0.3 m with a third of the size variation typically found in natural stands would satisfy most boreal loggers and haulers. The challenge is to produce such trees in the shortest possible time without multiple entries into the stand. This requires that stands be properly spaced when they are established.

The best way of minimizing risks with a forest whose future value and end use are uncertain is to keep its stands growing as vigorously as possible throughout their life. This will maximize the opportunities to adjust plans in midcourse as changes occur. Unfortunately, our present crop plans will decrease our chances of profit because growth will have slowed or stagnated before the likely key decision points are reached.

Crop planners must recognize that their objectives extend beyond simply growing trees. The decisions that they are taking, often with imperfect knowledge, have an impact on much more than the stand and its growth. What is or will be an asset cannot be established in isolation. The tradeoffs between growth rates, tree size, various costs and timing are such that crop planning must be a corporate activity.

SESSION III: Prime Site

SOME OPTIONS FOR PRIME LAND AND PRIME SITE CLASSIFICATION

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Abstract.--Prime site management consists of directing forest land management decisions in accordance with the highest overall return on investments. Prime land inventory--a land classification system that interprets mapped soil/site information with respect to inherent site productivity--can be used in directing timber management activities in Ontario at a strategic planning level. Its specific purpose, different scale and predictive capability complement existing site classification initiatives in Ontario. Five broad approaches to assigning soil/site conditions to a prime land class are presented, and their advantages and disadvantages are considered. Future acceptance and application of the prime site concept will depend on the reliability and accuracy of mapped interpretive data and on a clear understanding of its limitations in various planning and management activities.

Résumé.--La gestion des sites prioritaires vise à orienter les décisions en matière d'aménagement des terres forestières en fonction du rendement de capital global le plus élevé. L'inventaire des terres prioritaires--un système de classification des terres qui interprète les informations cartographiques sol/site en fonction de la productivité inhérente du site--peut servir à guider les activités de gestion forestière en Ontario au niveau de la planification stratégique. Sa perspective particulière, ses différentes échelles et sa capacité de prévision viennent compléter les diverses initiatives existantes de classification des sites en Ontario. Cinq grandes approches pour l'attribution des conditions sol/site à une classe de terre prioritaire sont présentées et leurs avantages et inconvénients respectifs sont analysés. L'acceptation et l'application futures du principle des terres prioritaires dépendront de la fiabilité et de l'exactitude des données cartographiques interprétées et de la bonne compréhension de ses limites dans les diverses activités de planification et de gestion.

INTRODUCTION

One of Ontario's most striking features is its seemingly endless expanse of forest--some 46.6 million ha, of which over 38.3 million ha are production forest (Anon. 1986). Our production forest covers the same area as the entire agricultural land base of the prairies and some 2.5 times the total area of Sweden.

The scale of forestry operations in Ontario is equally imposing. During fiscal year 1987-1988, the forest industry in northern Ontario accessed and harvested some 18.4 million m^3 of roundwood from 166,000 gross ha, the largest volume harvested to date (Anon. 1988). Woodbridge, Reed and Associates, in their recent report, **A Study of Ontario's Forest Products Industries** (1987), suggest that this harvest level is still well below the maximum allowable depletion, especially with respect to hardwood fiber. The potential for an increased harvest level is real. Artificial renewal treatments and maintenance of the new forest have similarly increased since 1960 (Fig. 1) (Anon. 1986), representing a total provincial regeneration budget for 1988-1989 of $200 million (industry contributions excepted) (Goodman 1989).

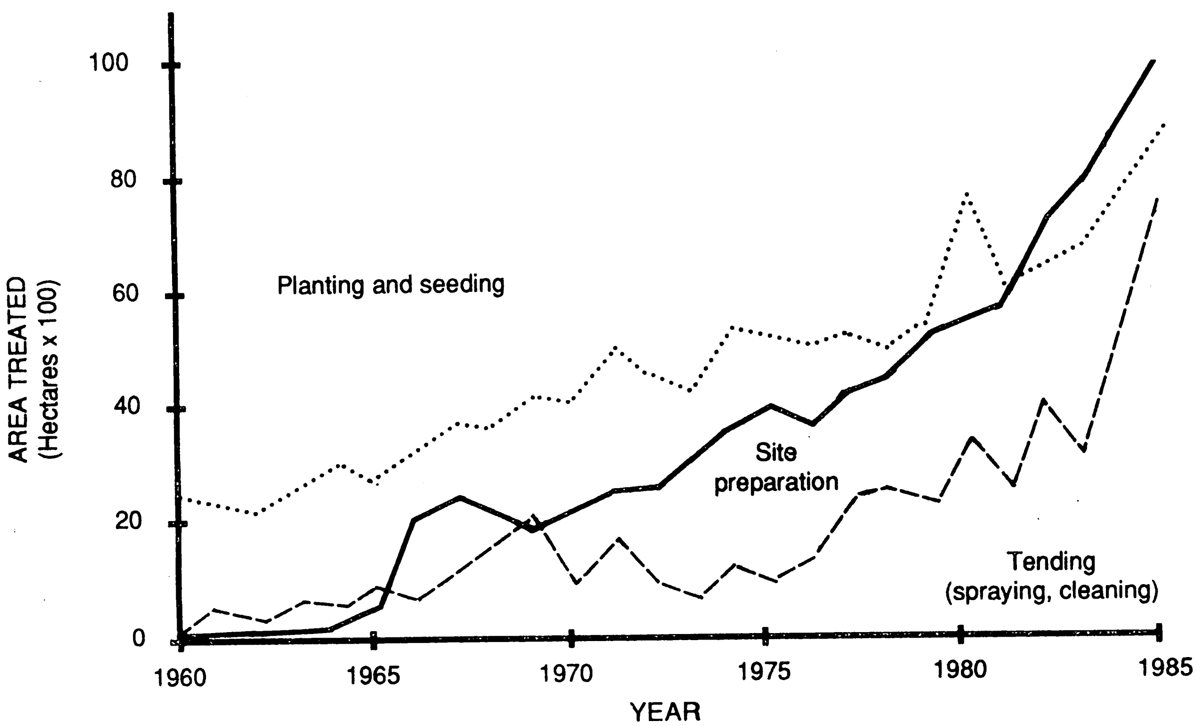

Figure 1. Planting and seeding, site preparation, and tending trends in Ontario (from Anon. 1986).

If we consider the expenditures, human effort and organization devoted to harvesting, reforestation and stand management operations, it is apparent that we need to do more than just create a "new forest". We must ensure that we maintain the existing natural forest while carefully fostering the development of new forests that will be industrial and environmental assets.

One requirement is to define the type of asset we want and identify the conditions that will lead to the creation of that forest. Garner (1989) presents one concept of a new forest, but there are numerous other possibilities. The challenge, like that of silviculture, is for us to examine those factors, using a rational, flexible and objective approach that will make the forest of tomorrow an asset (Fig. 2). But what should that approach be?

Why?

Conflicts? **Benefits?**

Where? **$** **How much?**

Cost? **How often?**

When?

The challenge is to find a logical, objective decision–making tool!

Figure 2. Prime-land classification and prime-site management are decision-making tools.

The productive capacity of the forest site is a critical factor in determining yield, product quality and, therefore, the relative value of the site as an investment opportunity. Both present and potential productivity of forested sites should be recognized as a cornerstone of any decision-making framework.

This paper reviews some concepts of prime-land and prime-site classification. It considers background and definitions, as well as some current approaches to identifying prime sites. Current constraints on applying prime-site concepts and factors that require additional attention are discussed.

PRIME SITE MANAGEMENT

Prime-site management is a decision-making support tool for documenting and analyzing management alternatives. Most practising foresters already undertake a form of prime-site management every time they are faced with a shortage of funds to purchase planting stock and must then decide which sites should be seeded, planted or left for natural regeneration. The big difference between 'gut-feel' and prime-site analysis is that we usually don't commit our objectives and rationale for certain decisions to paper, or consider economic factors such as return on investment or cost:benefit ratios in evaluating alternatives.

Prime-site management is defined as "the organizing and directing of timber management activities in accordance with the highest overall return on investment which will, in turn, optimize the use of public and private funding" (Jones 1986, Greenwood 1987).

A central tenet of this philosophy is that forest growth varies in direct proportion to potential site productivity. In the interests of economic efficiency, therefore, productive or 'prime' lands should receive top priority in management plans (although treatment intensities can and should vary). As well, it is agreed that soil features within a local area are the predominant indicator of site productivity or "primeness", and that these features can be readily observed, measured, mapped and utilized in timber management planning (Jones 1986, 1987).

The prime-site management approach had its origin in the United States with the Weyerhaeuser company on the west coast (Campbell 1978) and the International Paper Company on the east coast (Mader et al. 1984, Saviello 1984). Both of these major companies employed a "yield maximization-cost per m^3 minimization" strategy on their patent land holdings as a means of optimizing return on investment. Its applicability to and impact on existing management planning principles are now being investigated by the Ontario Ministry of Natural Resources (OMNR) in its Northern and Northeastern regions (Heikurinen and Kershaw 1986a,b; Teskey 1986; Greenwood 1987; Williams 1989).

PRIME-LAND CLASSIFICATION AND INVENTORY

Identification of prime sites depends largely on the ability to distinguish and classify the productive capacity of forest sites, and moreover, to determine where these sites occur. We need to know what interest rate Mother Nature is going to give on access, renewal and maintenance investments. This is considered the "prime-land classification and inventory" component of prime site management, and it involves "describing those soil/site conditions which support acceptable growth rates and volume production of the commercial species due to differences in the inherent capability of the soil/site to supply moisture and nutrients for forest growth" (Nicks 1985, Greenwood 1987).

Prime-land management in the United States began in the late 1960s as conservation of prime farmland. The objective at that time was to identify fertile, easily managed cropland and protect it from other uses. Existing soil surveys were interpreted in terms of crop productivity and were rated for protection.

In 1973 this program was extended to cover forested land. Prime land was defined as those sites with soil capable of growing wood at a rate of 5.8 m^3 wood/ha at the culmination of maximum mean annual increment in natural stands. This was calculated on a species-specific basis and was interpreted by correlating productivity with certain soil/site conditions. Maps and soil series descriptions were then amended to include this site productivity information. The program was often able to make good use of existing detailed soil survey information (Saviello 1984).

How we classify and interpret prime land in Ontario depends upon several criteria:

1) **scale of application**: What will be the "working level" of the mapped databases?

2) **existing land resource information**: What kinds of other maps and information are already available for different areas, and at what scales and levels of accuracy can they be used? What are their limitations, particularly for forestry interpretations, and how might these be mitigated?

3) **desired level of accuracy**: What degree of accuracy and ground checking is required in the final product, and how will this be determined? How accurately must the final polygons be defined?

4) **desired level of reliability**: What degree of reliability is needed for decision making? What degree of error is acceptable for interpretations?

5) **correlated species:soil/site productivity data**: What is required or available in the way of correlated soil/site productivity data so that growth or yield predictions may be made on a site-by-site basis? How can this information be integrated into interpretation and decision-making procedures for prime sites?

There is also a need to understand one critical point: that classifications are intended for specific purposes and cannot serve all information needs. Most land classifications in Ontario are **descriptive** of the resource base whereas prime land is an interpreted inventory (Fig. 3). Use should be made of whatever data elements are common to various site, soil, land and terrain classifications as a means of reducing workloads and standardizing technologies.

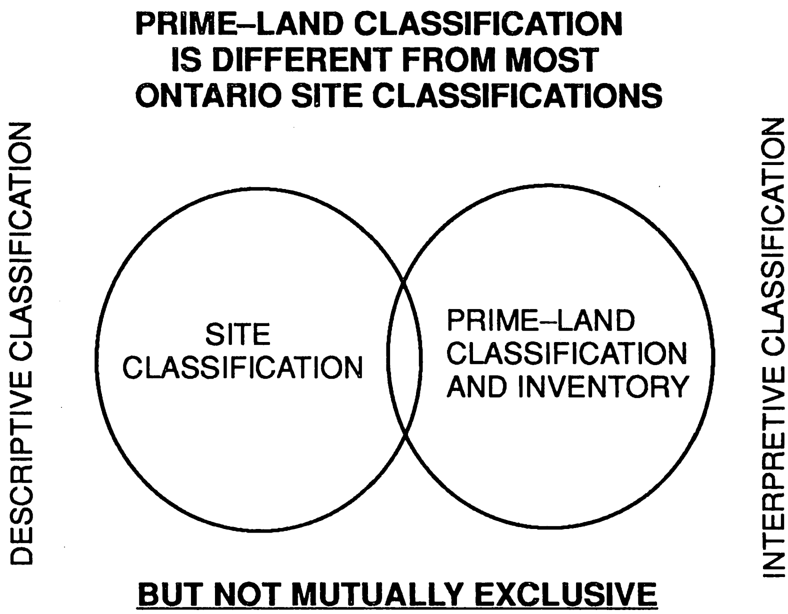

Figure 3. Prime-land classification and site classification are complementary.

Two approaches are commonly employed to describe site productivity (cf. Carmean 1975):

a) Direct:

- absolute volume production per unit area per unit time
- rates of production (maximum mean annual increment [MAI])
- height growth stratified by MAI
- height growth stratified by a basal area factor

b) Indirect:

- height growth (site index predicted on the basis of soil)
- qualitative (good, medium, poor).

Each of these methods is a means to an end, i.e., gaining access to yield table and volume information (e.g., Plonski 1984, Kershaw 1988).

Once again, the appropriate measure for describing site productivity depends heavily on available information, the cost of acquiring additional information, and the need to quantify yield accurately and reliably for economic evaluations.

APPROACHES TO CLASSIFYING SITE PRODUCTIVITY

There are at least five approaches to, or models for, classifying prime land. These approaches are considered briefly here, along with some of their individual advantages and disadvantages.

The Expert Opinion Model

Expert opinion may be applied when there is a general lack of quantitative data or detailed model information. It can be used to help integrate many items into an interpretive framework.

The advantages are many, and include the following:

- it produces immediate answers
- it is logical to users
- it produces consistent interpretations that can be tested
- it is easily updated in response to new information
- it may be used by non-experts
- it is inexpensive.

The disadvantages are also self-evident:

- it is only as good as the experts' understanding of the system in question
- it is often applied to conditions for which it was not developed
- it is usually non-quantitative and therefore not very defensible.

Examples include OMNR's Northern Region prime-land algorithm (Fig. 4; Nicks 1985, Greenwood 1987), Hills' (1952, 1953) site regions and districts for Ontario, the method for rating site operability included in the Northeastern Region's forest-management potential matrix (Heikurinen and Kershaw 1986a,b), and the method by which many of our field staff select stands for harvest and renewal.

Classification of expert opinion requires verification and amendments in response to quantitative data. As an example, the Northern Region prime-land key was applied to a number of North Central Region sites for which there were jack pine (**Pinus banksiana** Lamb.) site index data (Fig. 5). The resulting large number of non-significant differ-

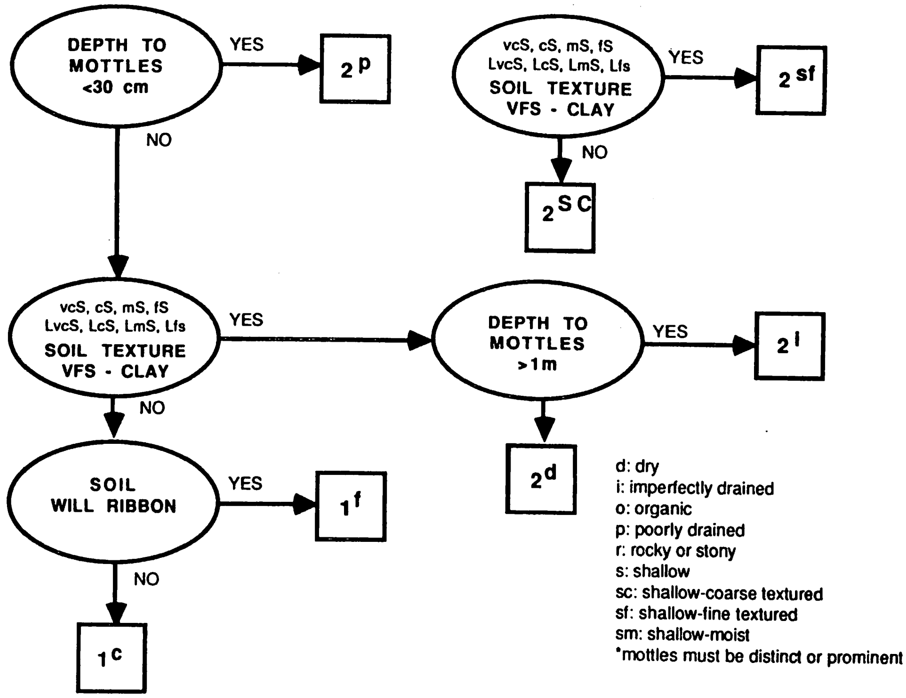

Figure 4. A portion of the OMNR's Northern Region prime-land key (Nicks 1985), an example of the expert-opinion approach.

ences between the mean site-index values for each of the classes and subclasses suggests a need to modify this key, if it is to be applied in the North Central Region.

Taxonomic Model

The taxonomic prime-site model uses results of growth and yield observations from defined taxonomic classes, such as Forest Ecosystem Classification (FEC) (Sims et al. 1986, 1987) types, to predict site productivity in other areas with similar classes.

Advantages to this approach include the following:

- it provides quantitative descriptions that can be statistically significant if properly sampled
- it utilizes other land-resource information
- it is easily visualized by the practitioner
- it may incorporate the impact of climate or other major variables on production.

Disadvantages to this approach include the following:

- it requires stratified sampling and extensive data sets
- it is often applied to forest site conditions for which it was not designed
- its effectiveness depends on the accuracy of the initial classification and the rationale used in defining it
- covariance and factor interaction are often encountered
- it is expensive.

The taxonomic approach is demonstrated by using site index at 50 years breast height age (Table 1) to characterize various FEC soil types for jack pine productivity. Although some soil types are statistically different, many have non-significant differences. This suggests that the soil features used by the FEC to classify soil are not those most directly influencing or directing jack pine growth and productivity.

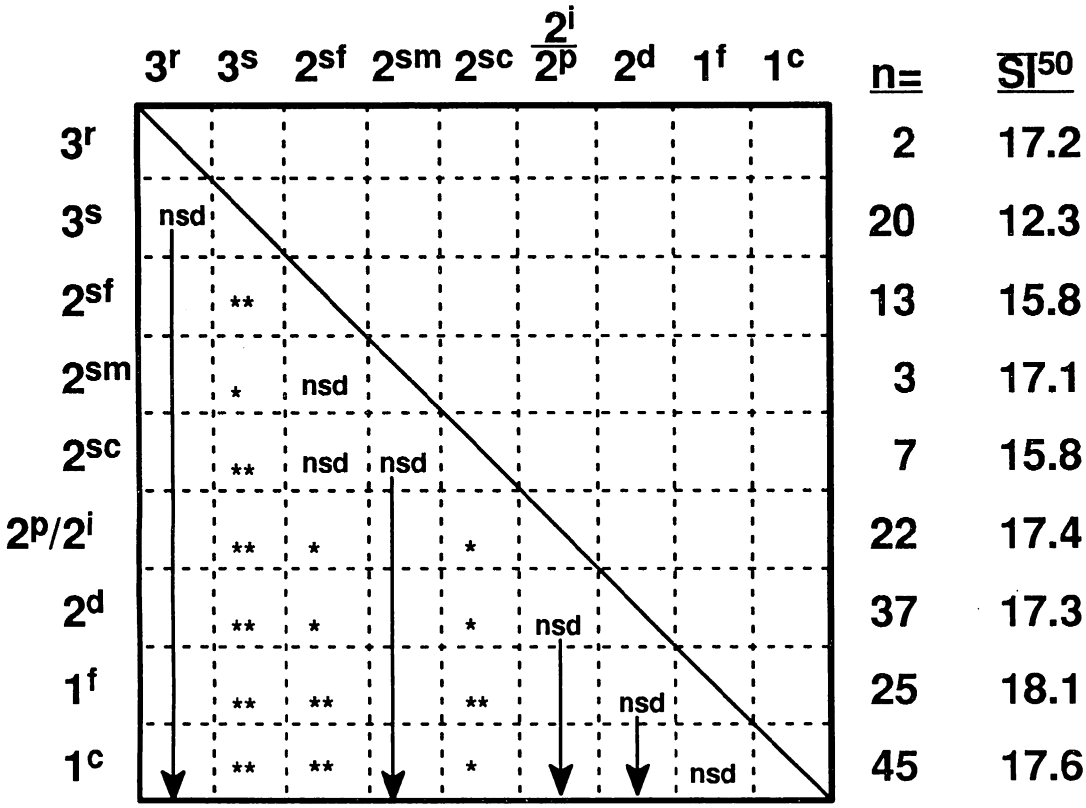

Figure 5. Expert-opinion models require verification and amendments in response to quantitative data. This figure shows the results of an unpaired t-test of mean site index values for jack pine for each of OMNR's prime-land classes and subclasses: * = difference significant at p = 0.05, ** = difference significant at p = 0.01, nsd = no significant difference. (data from the North Central Region)

Table 1. Taxonomic models use results of growth and yield information from defined taxonomic classes such as the Forest Ecosystem Classification, e.g., Jack Pine Site Quality for North Central Region Site Index at 50 Years Breast Height Age (Unpublished).

Description	FEC soil	No.	Mean (m)	Range (m)	SD	Sx
Dry, very sandy	S1	9	16.7	14.2-18.4	1.37	0.46
Dry, coarse, sandy	S1	23	18.3	13.9-21.6	1.86	0.39
Fresh, fine, loamy, coarse, loamy, fine, sandy	S2, S3, S4	61	17.5	12.6-22.4	1.96	0.25
Fresh, clayey	S6	10	19.0	17.2-20.5	0.97	0.31
Moist, coarse, loamy, sandy, silty fine loamy-clayey	S7, S8, S10	31	17.1	11.9-21.6	2.30	0.41
Shallow <5 cm	SS1, SS2	4	9.5	8.6-10.1	0.68	0.34
Shallow >20<75 cm	SS3	12	13.3	9.3-17.7	2.90	0.84
Shallow >20<75 cm	SS6	16	14.9	9.3-17.1	2.37	0.59
Shallow, moist-imperfectly drained	SS7, SS8	10	16.4	13.5-18.8	1.72	0.54

Empirical Model

Empirical relationships involve predicting the prime-land class for a site on the basis of observation or experience of a given population. This usually involves the derivation of statistical equations.

The advantages to this approach are that it:

- provides an objective measure of reliability or confidence when used appropriately
- is quantitative
- handles the soil/site variability found in the forest
- is inexpensive
- indirectly addresses the impact of climate on production.

The disadvantages include the following:

- success in correlating soil criteria and growth/site index measurements has been variable
- it is often influenced by variable stand density, disturbance and age
- it requires independent validation
- mechanisms governing the growth response are not always identified by the process
- models often include variables that are difficult to detect or observe under field conditions
- it is restricted to the range of conditions for which the model was developed.

An example of an empirical relationship that predicts site quality is the soil-site prediction equations developed for jack pine in the North Central Region (Table 2; Schmidt 1986, Schmidt and Carmean 1987). Knowing certain soil/site parameters one can predict the expected site-index class for jack pine on the site and relate it to volume tables.

Calibration Model

The calibration model uses indirect measurement approaches to estimating site or stand productivity. Relationships between productivity functions and more easily measured parameters are first established, then calibrated for a range of conditions, and finally a network of interpretations is made. It may be considered a "variant" of the empirical approach.

Table 2. Empirical models that predict growth and yield attributes with statistical equations.

Landform	No. of plots	Equation[a]	R^2	SEE
Shallow to bedrock	20	SI = 9.42 + 0.11 DBR - 0.0006 (DBR x CoFrag A)	0.83	1.28
Glaciofluvial	31	SI = 17.56 + 0.10 DRL - 0.73 slope - 0.0044 [DRL x (20 - slope)]	0.65	1.26

[a]SI = Site index [total height (m) of dominant and codominant trees at 50 years breast height age], DBR = depth to bedrock (cm), DRL = depth to restricting layer (cm) (i.e., coarse sandy subsoil, moities, gley, water table, bedrock, carbonates or basal till), slope = slope steepness (%)

The advantages are that it:

- provides an objective measure of reliability or confidence when used appropriately
- is quantitative
- handles soil/site variability found in the forest provided that the calibration has been conducted over the full range of conditions
- is inexpensive
- indirectly addresses the impact of climate on production.

The disadvantages include the following:

- it requires field measurements and a research component in order to develop and verify a calibration system
- it may be influenced by variable stand density, disturbance and age, as well as by other factors
- it requires independent validation
- mechanisms governing the growth response may not be identified by the process
- it is restricted to the range of conditions for which the model was developed.

Timmer (1987) and Timmer and Ray (1987) describe an approach to estimating black spruce (**Picea mariana** [Mill.] B.S.P.) productivity and site quality in the Clay Belt of Ontario by undertaking indirect measurements of needle chemistry, and calibrating these results with FEC types.

Process-related Model

This approach to classifying prime land requires the development of a process-related model. Such a model, describing dynamic processes and soil/site/climate interrelationships, is very difficult and time-consuming to develop, but may be highly flexible for addition of new information, or, for example, for application to new problems, different areas or time-series problems.

The advantages are that it:

- is dynamic and easily updated
- can be used to predict responses to management decisions

- produces reliable results when calibrated
- is process orientated
- predicts future productivity.

The disadvantages are that it:

- is not easily applied in the field
- includes variables that are difficult to detect in the field
- often requires long-term data from permanent sample plots for calibration
- is expensive and time consuming
- requires geographically based information for the important variables in order to develop and refine the model
- often requires estimation of variables.

One of the few functioning examples of a process-related approach is the FORCYTE model developed in British Columbia (Kimmins 1986, 1987).

CONCLUSIONS

There is more than one acceptable way to "debark a log" when it comes to classifying and inventorying prime land. It really depends upon the urgency of the need, the existing resources to do the work, the scale of inference, and the reliability and accuracy of the predictive function. There are, however, some characteristics that should be sought in the final prime-land product. The resulting prime-land classification should be:

- simple
- easily understood and read
- easily adapted to different forest environments
- practicable (it must work and be accurate/reliable)
- cost efficient.

Attention in this paper has been focused more on the classification of prime lands--the cornerstone of prime-site management--than on prime-classification itself. It should be recognized that other factors, such as the following, contribute to the determination of biologically and economically efficient 'prime' sites:

- specific management objectives, e.g., wood supply
- the existing forest resource (quality, quantity, value, growth)
- current silvicultural "know-how"
- financial and human resources
- economic decision-making
- alternative land and resource uses
- resource location and access.

Since most field foresters already practise a kind of mental prime-site management strategy when faced with silvicultural and harvesting choices, it must be asked: "We could be doing it now, but why aren't we?"

Some of the answers to this question may relate to:

- the misconception that elaborate technologies must be developed and brought into the scheme before prime-site management can begin
- decisions about dealing with the dynamic world of changing economic criteria and needs (e.g., how best to optimize, maximize, minimize)
- inadequate or nonexistent quantitative information on site productivity
- divergent government and industry management objectives concerning what is to be optimized or maximized
- limited funds, time and trained individuals to practise holistic planning and management
- the lack of demonstrated application and benefits of this procedure.

There is one additional consideration. Must there be a standardized approach to prime-site determination and allocation throughout northern Ontario? It may not be necessary and, in view of the broad range of conditions, available databases, different requirements for end-use and other factors, it may not be desirable.

To move prime-site management from the dreaming stage to the forest we need:

- technology/information transfer and feedback at the field level
- a marriage of geographic information systems (GIS) and strategy to make the process dynamic and responsive to temporal, spatial, value, and use changes occurring in our forest
- staff training and time to apply the procedures
- more and more refined site productivity and yield information.

In the meantime, northern Ontario field foresters can start to apply prime-site management on a stand-by-stand basis while considering how best to undertake forest-level planning. Let's look for the opportunity to create that new forest that will be an asset to both the industry and the public of the future. Remember: progress is slow because nothing is ever invented and perfected at the same time.

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MODELING REGIONAL TIMBER SUPPLY IN ONTARIO'S NORTHERN REGION

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Abstract--A methodology for analyzing wood supply and forest investment problems is presented, with the Ontario Ministry of Natural Resources' Northern Region timber supply model NORMAN as an example.

Résumé--Présentation d'une méthode d'analyse des ressources en bois et des problèmes d'investissement en exploitation forestière en prenant comme exemple le modèle NORMAN (ressources en bois dans la région du Nord) du ministère des Richesses naturelles de l'Ontario.

INTRODUCTION

Forest management budgets across Canada have increased dramatically since the late 1970s. In Ontario alone, provincial expenditures increased from $87 million in 1977 to $191 million in 1985, a real increase of 39% (Anon. 1987). The impact on silviculture programs of these changes in forest management budgets has already been felt. For example, Figure 1 shows the increase in planting, tending and site preparation in Ontario from 1975 to 1987. However, the Ontario Ministry of Natural Resources' (OMNR) Northern Administrative Region has been unable to measure the effect of these changes on sustainable wood supply or to determine whether its forest management program is adequate for meeting its wood supply targets.

For this reason, the Northern Region is constructing the first version of a volume-based wood supply model called NORMAN (Northern Region Management Model) to determine:

1) the feasibility of meeting forest production policy targets on the current forest management budget

2) the impact of change in forest management budgets on sustainable harvest levels

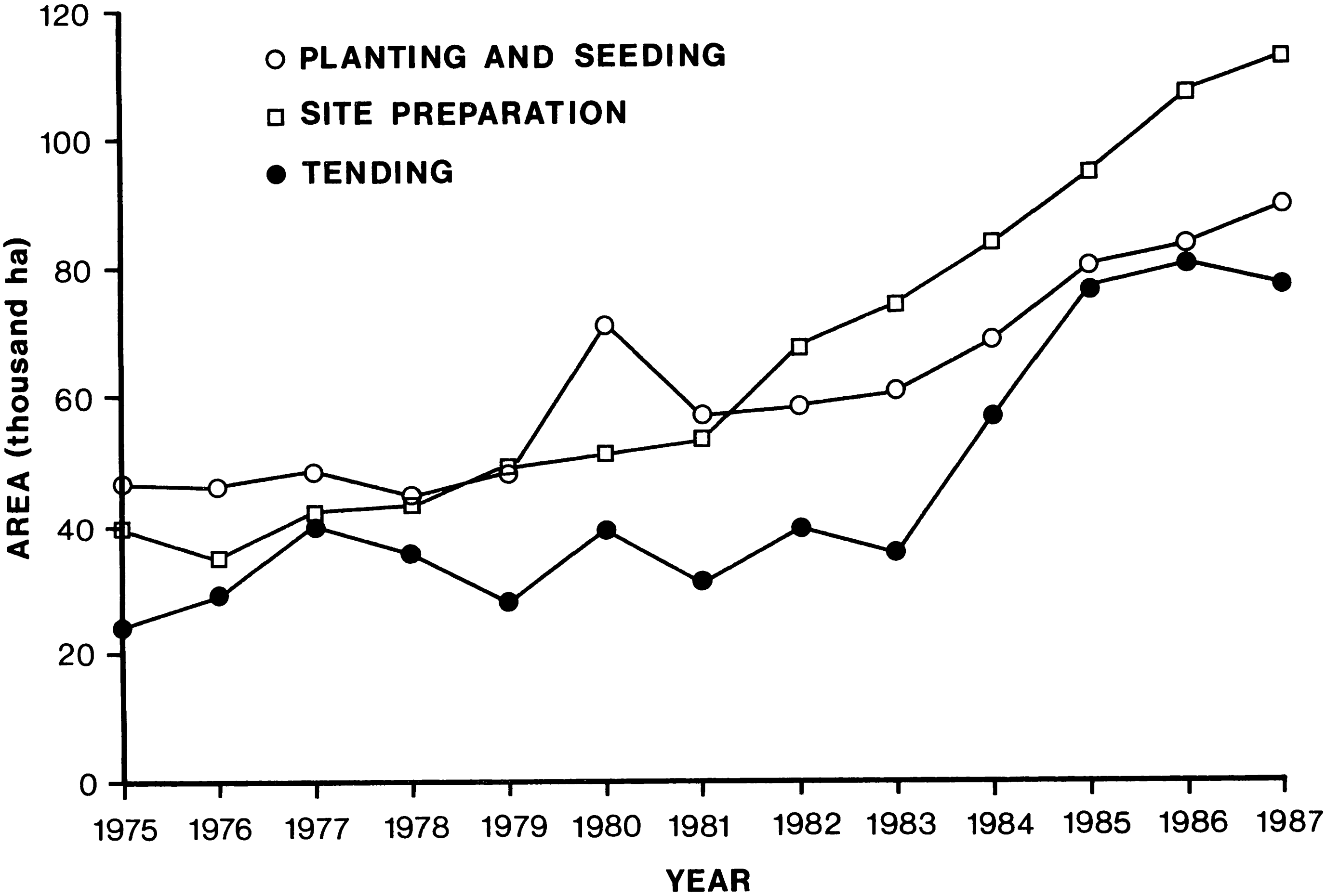

Figure 1. Increases in planting and seeding, site preparation and tending in Ontario from 1975 to 1987. (Statistics obtained from Anon. 1980, 1984, 1988)

3) the impact of different harvesting strategies on sustainable harvest

4) the impact of different silviculture strategies on sustainable harvest

5) specific areas within the region in which wood supply deficits or surpluses might occur. (These will be quantified in terms of merchantable roundwood.)

NORMAN: NORTHERN REGION MANAGEMENT MODEL

The NORMAN model is composed of a series of data-base applications that link a modified FORMAN model (FOREST MANAGEMENT MODEL) to the Forest Resource Inventory (FRI) and to a series of simple growth projection models. FORMAN is a "sequential inventory projection model" developed to analyze alternative forest management strategies[1]. FORMAN is a simulator rather than an optimizer and therefore does not attempt to find the best alternatives on the basis of a predefined objective function. It simply shows the response of the forest (e.g., projections of inventory growing stock, harvest, management costs) to specific forest management options.

FORMAN uses time-dependent relationships such as yield per hectare versus age and requires the linkage of these relationships to aggregations of forest stands called forest classes. The steps in preparing the necessary inputs to FORMAN are: 1) aggregation of the FRI into forest classes, 2) development of natural and managed-stand growth curves, 3) projection of standing inventory volumes, 4) definition of operating constraints, 5) definition of management alternatives specific to each forest class. We have attempted to streamline this process by using data-base management software to link the FRI to the FORMAN model. This software simplifies the creation of the input files required to run the FORMAN model. Figure 2 shows how these automated procedures are related and how they provide input to the FORMAN model.

DATA PREPARATION

Data Aggregation

Most wood supply models, including FORMAN, use aggregated rather than individual forest-stand data to make wood-supply projections. The aggregation of stand data in forest classes results in the loss of spatial resolution and subsequent difficulties in implementing model-generated harvest and silviculture schedules (Erdle and Jordan 1984, Hoganson and Rose 1984, Rose 1985). Only recently have methodologies been developed to deal with unaggregated stands (Rose 1985), and these are not yet widely used or available.

The question of which stands should be grouped into forest classes is an important one that relates directly to the management questions being asked. Usually, stands are grouped on the basis of similarity of operational practices, items produced, response to silvicultural treatments and environmental influences. The spatial scale of the analysis is also important. For example, it may be desirable to track the development of individual stands at the management unit level, where operational plans are implemented on the basis of individual stands, but not when the focus of the management questions is broad, as at the regional level.

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[1] Wang, E., Erdle, T. and Roussell, T. 1987. FORMAN wood supply model user's manual, version 2.1. N.B. Dep. Nat. Resour. Energy. Fredericton, N.B. 61 p. Unpubl. Rep.

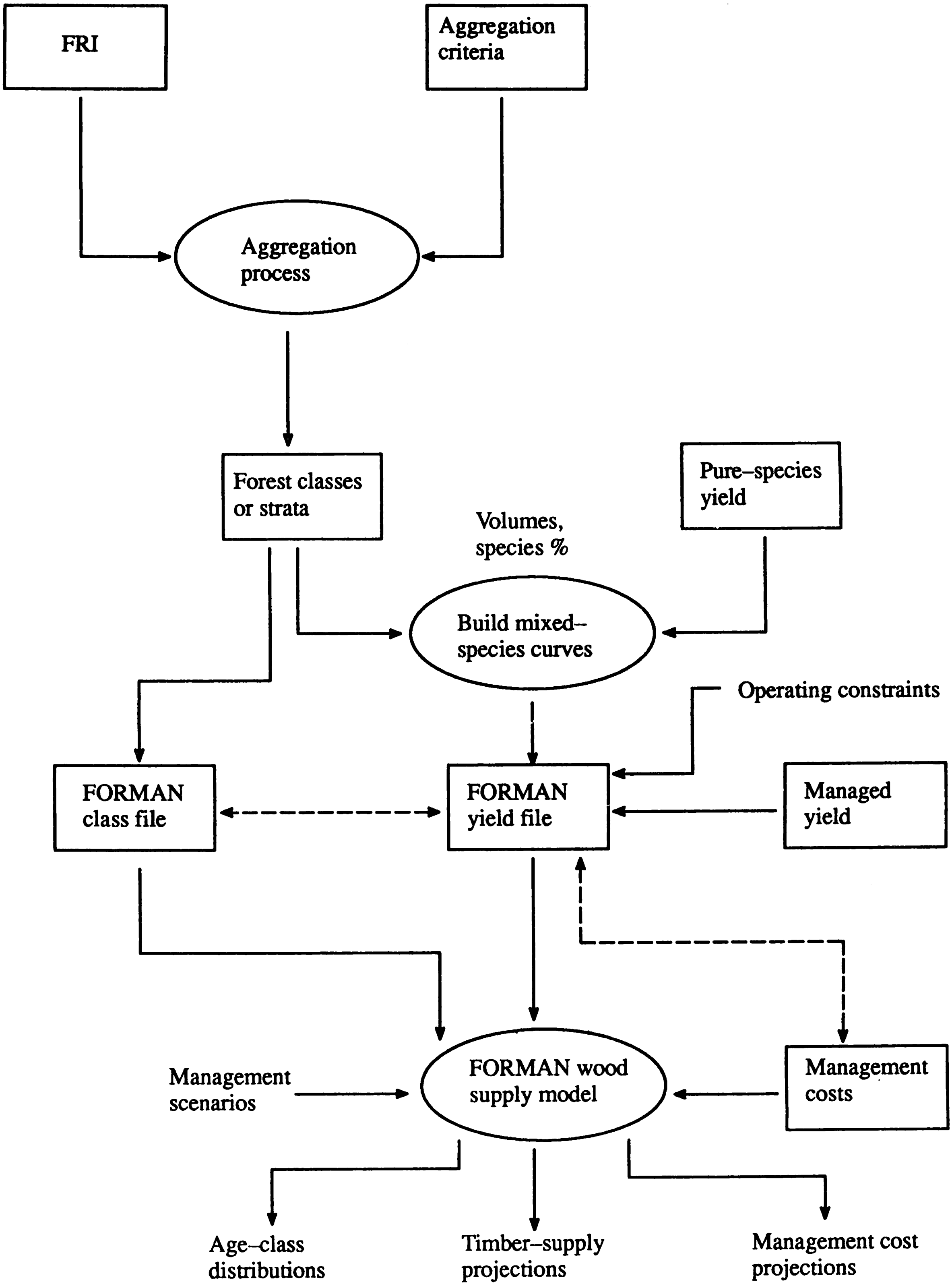

Figure 2. Data flow in the NORMAN model.

The FRI for the Northern Region supply analysis was aggregated by working group, site class, crown ownership and age class for each management unit in the region. The representation of management units (Fig. 3) in the model adds a spatial dimension that will be important for determining where local wood supply problems may arise and where surpluses exist.

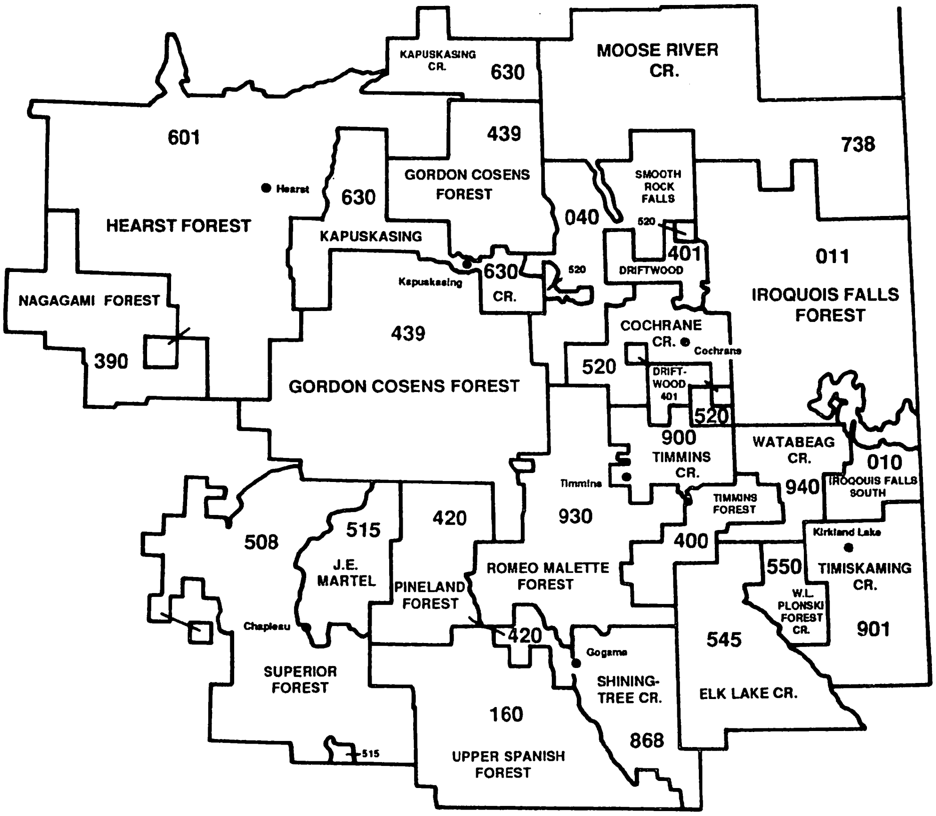

Figure 3. Management Unit boundaries in the Northern Region.

Since the regional FRI is large the process of aggregation has been automated. The flexible aggregation programs being developed allow us to aggregate the inventory according to different stand attributes or criteria, and so address different management questions as they arise. The aggregation program developed in the Northern Region groups all forest stands in the FRI data files that meet forest class definitions (e.g., jack pine working group, site classes X and 1, Crown ownership, age 41-60 years) and stores the aggregated data from the stands in a forest class file. These files contain information on forest-class area, average height, working groups, site classes, average stocking, average stocking of each species within a class and average net merchantable volume of each species within a class. These class files can be accessed with report-writing functions that generate reports such as that shown in Table 1 and the necessary input-file structures for the wood-supply models and growth-projection procedures.

Table 1. Portion of an inventory report, showing age class, average age, working group (WG), site class, area and average net merchantable volume per hectare, by species, of the class.

Age class	Avg age (yr)	WG	Site class	Area (ha)	Volume (m³/ha) Sb	Sw	Pj	Bf	Po	Bw	Soft-wood	Hard-wood
101-120	109	Pj	1	244	44	3	91	16	12	19	154	31
61- 80	69	Pj	1 X	3368	24	2	152	6	21	7	184	28
61- 80	68	Pj	2	7290	28	1	111	4	12	5	144	17
81-100	91	Sb	X 1	3447	57	7	16	7	7	5	88	12
61- 80	74	Sb	1 2	645	46		5	2	2		55	2
1- 20	15	Sb	1	354								
101-120	106	Po	3 2 1	377	25	23	12	8	90	13	68	103
61- 80	71	Po	3 2 1	6029	14	9	20	12	101	17	56	118

NOTE: Pj = jack pine, Sb = black spruce, Sw = white spruce, Bf = balsam fir, Po = poplar, Bw = white birch.

Growth Projections and Operating Constraints

The next step in the wood-supply modeling process is the projection of current standing volumes in each forest class. Since most of the forest classes defined for the analysis had significant components of species other than the working group species, it was necessary to account for species mixes in growth projections. This was done by following a procedure developed and approved by the New Brunswick Forest Research Advisory Committee's Wood Supply-Growth and Yield Technical Committee[2], which is based on the assumption that species-specific development remains proportionally the same over a broad range of species combinations.

The application of this procedure in the Northern Region began with the construction of pure-species yield curves for the commercial species found in the region (Fig. 4). The growth curves used in the analysis are based on existing literature, stem analysis data and some permanent sample plot data. While these estimates are not perfect, they represent our best current knowledge.

Growth rates were then calculated by dividing the volume at each age on the yield curve by the volume at the previous age on the curve (Table 2). The volumes, by species, for each forest class were projected by using the growth rates associated with that species' pure-species yield curve at the appropriate age. For example, in a stand composed of 50% spruce and 50% jack pine, the pure-species spruce growth rates are used to project the spruce volumes and the pure-species jack pine growth rates are used to project the jack pine volumes (Fig. 5).

[2] Anon. 1987. Yield curve construction for natural stands, guidelines. New Brunswick Forest Research Association - Growth and Yield Technical Committee. Fredericton, N.B. 26 p. Unpubl. Rep.

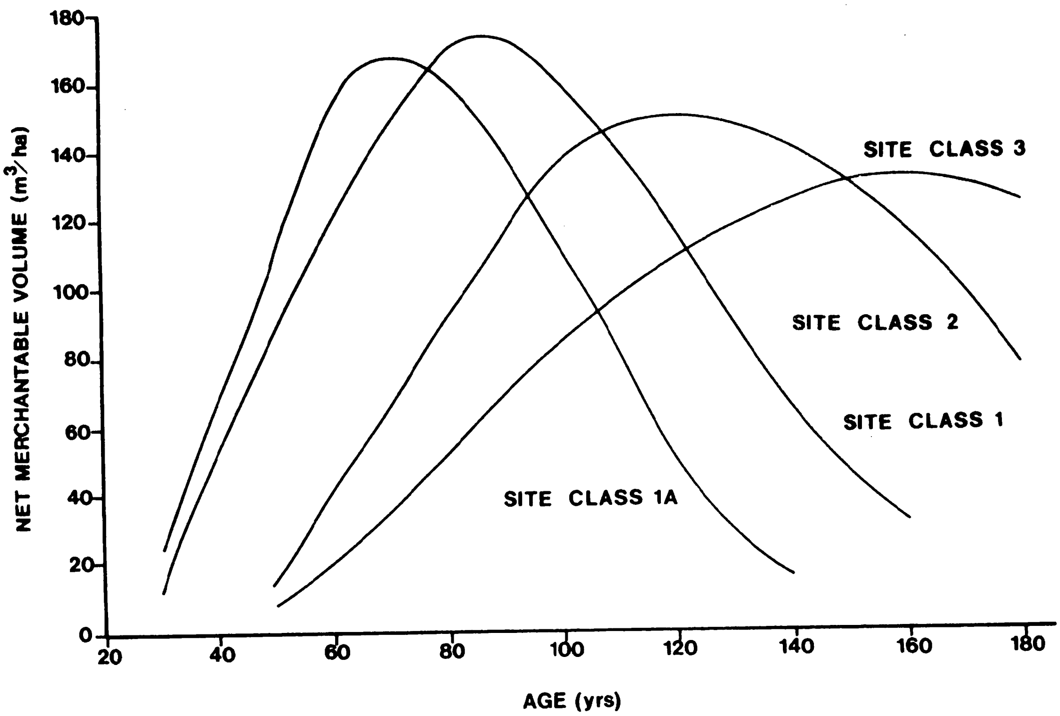

Figure 4. Pure-species yield curves, showing net merchantable volume per hectare for black spruce, were developed from Smith (1983)[3] and Woods and Beckwith (1987).

Table 2. Calculation of growth rates along a portion of a yield curve.

Age (yr)	Volume (m^3/ha)	Growth rate (m^3/ha/yr)
30	12	32/12 = 2.67
35	32	1.62
40	52	1.31
45	68	1.23
50	84	1.21
55	102	1.16
60	118	1.10

[3] Smith, V.G. 1983. Black spruce empirical yield tables. Prepared for Ontario Ministry of Natural Resources, Northern Region, Timmins. Univ. Toronto, Fac. For., Toronto, Ont. Unpubl. Rep.

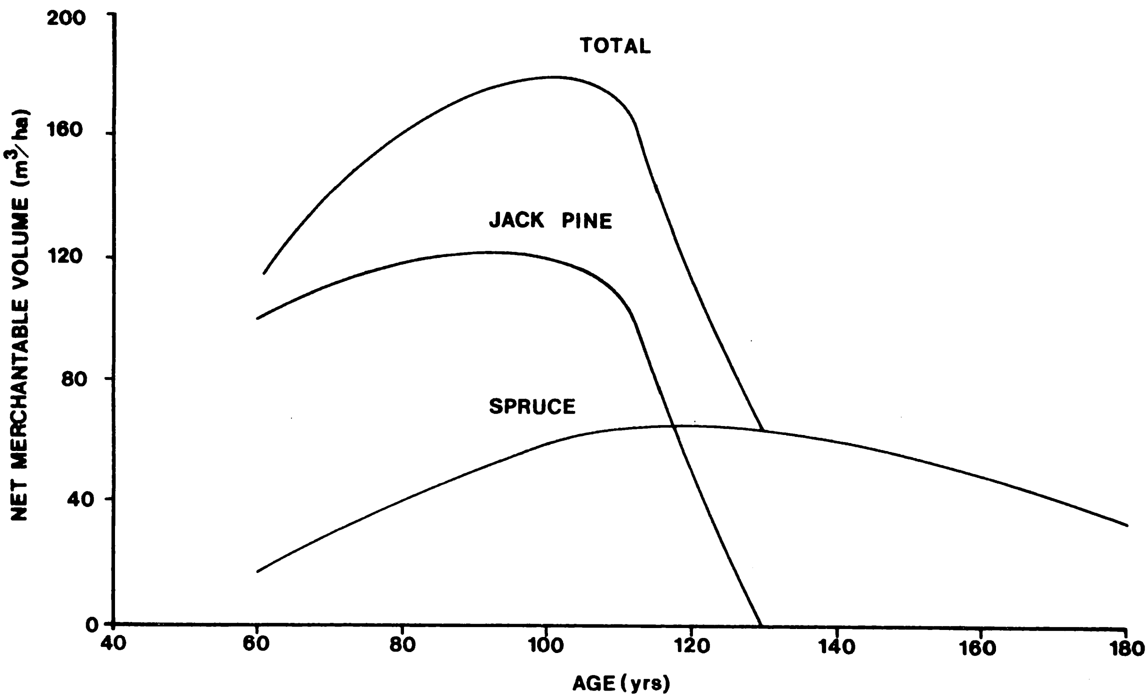

Figure 5. Methodology for projecting yields of mixed-species forest classes. In this example, the forest class had an average age of 60 years and was composed of jack pine and spruce. The jack pine yields were projected by using growth rates along the jack pine pure-species yield curve and the spruce yields were calculated by using growth rates along the spruce pure-species yield curve.

Operating constraints were defined for both growth and decline phases of each yield curve. They were based on the minimum size of harvestable piece for the growth phase of each curve and on minimum harvestable volume per hectare on the decline segment of each curve.

Management Alternatives

Once the forest classes were defined, management alternatives were developed for each class. In the first version of the NORMAN model only two management alternatives were provided for each forest class: managed and natural regeneration. These alternatives reflect typical management techniques for the particular forest classes. For example, the managed-stand alternative for site class 1 spruce might represent clearcut, mechanical site preparation, plant, and a herbicide treatment. The managed-stand alternative for site class 3 spruce might represent a situation in which special harvesting methods are used to protect advanced regeneration, and minimal planting and/or seeding are done.

The outputs (yield per hectare) were then defined as illustrated in Figure 6. Yield per hectare is based on scant information but represents our best current estimate of yield for a managed stand.

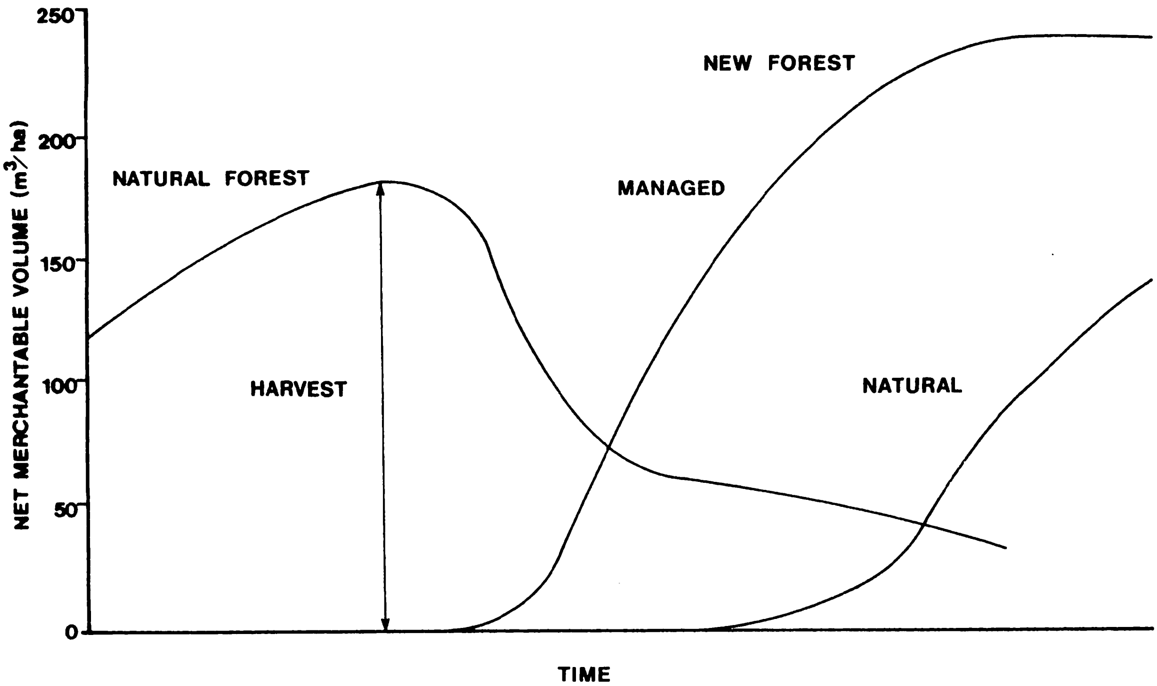

Figure 6. Two management alternatives were specified for each forest class.

Finally, a cost was assigned to each of the management alternatives specified for each forest class. The cost per hectare was determined by identifying a sequence of activities leading to managed stands. The total cost for each management regime was calculated by adding the known average costs for each activity in the regime.

WHAT DO WE INTEND TO ACHIEVE?

The most important relationship that we intend to generate with the FORMAN model is that between dollars of forest management input and long-term sustained yield (Fig. 7). This relationship will be developed by iteratively running the FORMAN model at different forest management budget levels to determine sustainable harvest levels for each budget level. The forest management budget/sustainable harvest level relationship will be important for setting and adjusting wood supply targets and for measuring the impact of budget constraints on wood supply.

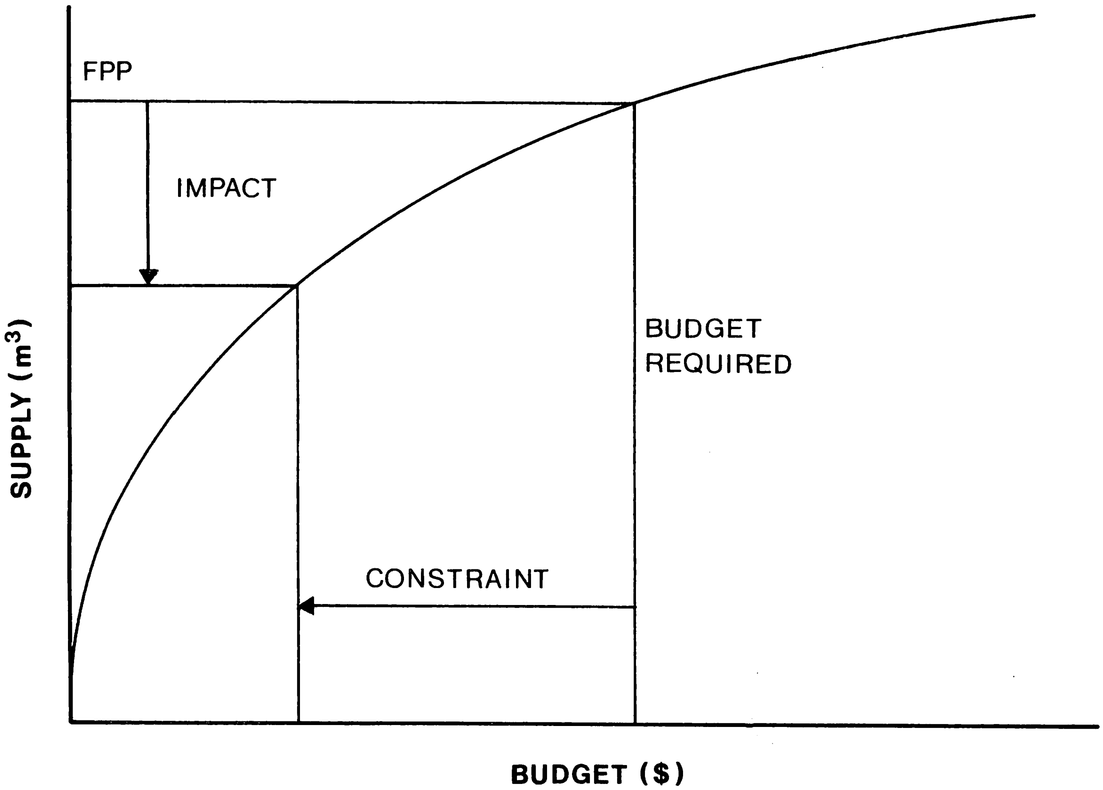

Figure 7. The relationship between long-term sustained yield (m^3/yr) and forest management budget. This relationship can be used to determine the budget required to meet the forest production policy (FPP) and the impact of forest management budget changes on long-term sustained yield.

An important assumption behind this relationship is the principle of non-declining sustained yield, i.e., total harvest from the forest may rise but not fall. The level of present and future wood supply under this assumption is very dependent on age-class distributions such as that shown in Figure 8. The relatively low frequency of forest stands in the 1- to 60-year age classes means that the supply of wood will have to come from the abundant but slow-growing old forest until the areas that are artificially and naturally regenerated today are ready to harvest. The problem is compounded by the fact that this old forest is probably losing merchantable volume faster than it is gaining it. If the non-declining yield assumption were strictly enforced under these conditions, the supply of wood from the higher age classes in the forest would have to be stretched

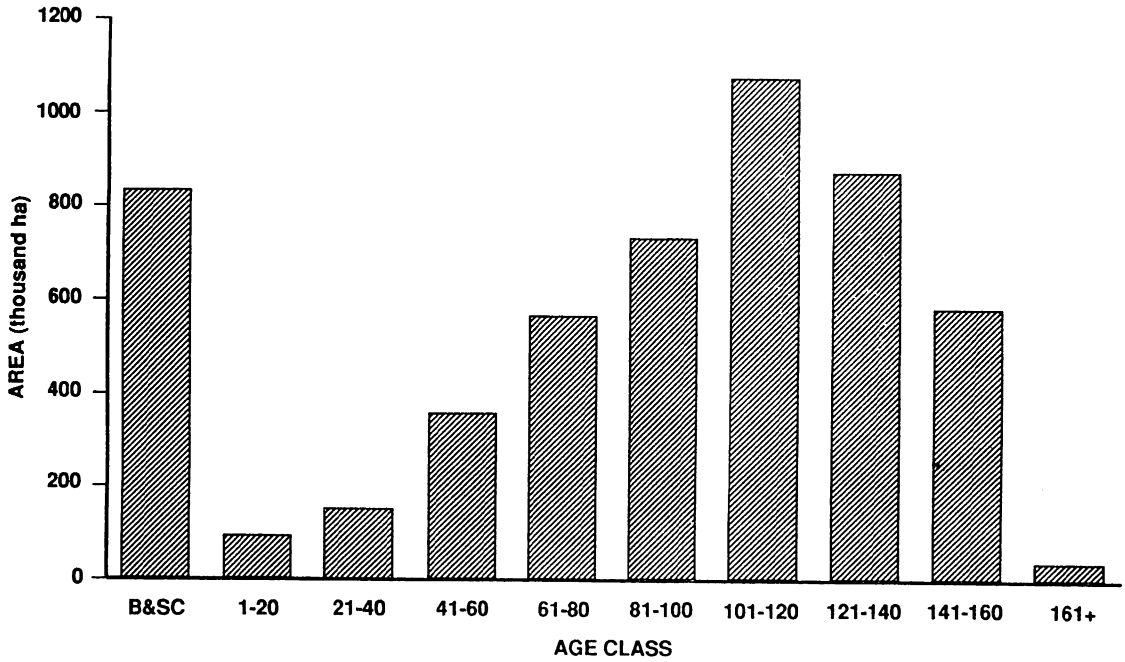

Figure 8. Age-class distribution of the black spruce working group in the Northern Region.

out over time until the young new forest was ready to harvest. This would affect **current** wood supply as shown in Figure 9, even though existing stocks of old-growth timber appear to be abundant. On the other hand, under a non-declining sustained yield policy, silviculture investments that increase forest productivity can increase the present wood supply through the allowable cut effect (Binkley 1980).

The long-term sustained yield/budget relationship will also depend on the harvest schedule employed. The FORMAN model simulates a number of harvest scheduling rules that change the priority and allocation of forest classes for harvest. These harvesting rules range from strict "oldest-first" policies to minimizing volume or mortality loss or maximizing harvested volume per hectare. The FORMAN model's scheduling rules will be used to simulate the impact of different harvesting strategies on the long-term sustainable harvest/budget relationship (Fig. 10).

Once the basic relationships have been established, sensitivity analysis will be performed on a number of inputs to the model. This will involve running the model many times while varying different inputs to the model across a range of values, as well as determining the effect of land-base withdrawals and reserves on timber supply by adjusting the percentage of area in each forest class available for harvest. Spatial effects and constraints on management will be analyzed by limiting the harvest levels to specific districts or management units. The sensitivity of the economic supply of wood will be analyzed by adjusting the operability constraints on each yield curve. Finally, the sensitivity of wood supply to

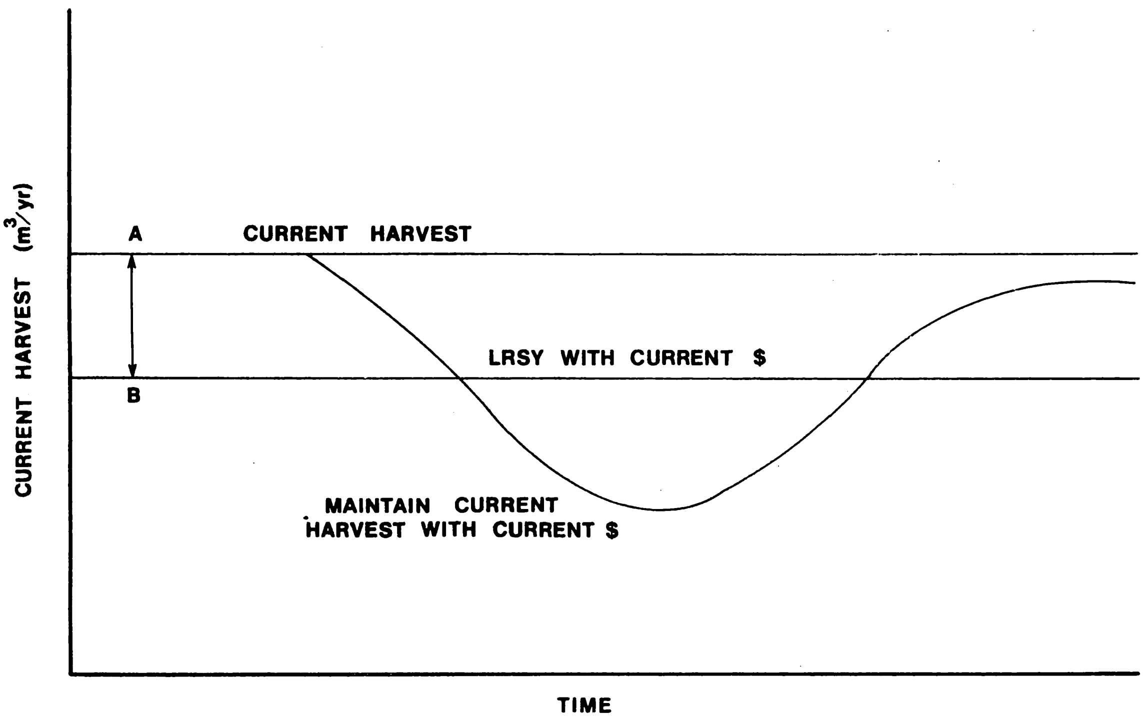

Figure 9. Effect of the non-declining sustained yield constraint on current timber harvest if current forest management budgets are not high enough to maintain non-declining yield at current harvest. If the non-declining sustained yield assumption were strictly followed, the current harvest should fall from A to B. If one attempted to maintain current harvests above the non-declining sustained yield level the harvest would eventually fall below the sustained yield level, as shown.

yield assumptions will be determined by adjusting the slopes of the growth and decline phases of the yield curves and by shifting the curves through a range of values that reflects the uncertainty surrounding our growth and yield information. Figures 11 and 12 illustrate the uncertainty associated with wood supply as a result of the uncertainty associated with growth and yield models.

Sensitivity analysis should help us to identify the crucial variables in the model of wood supply and thus help to set priorities for technology-development and information-gathering exercises.

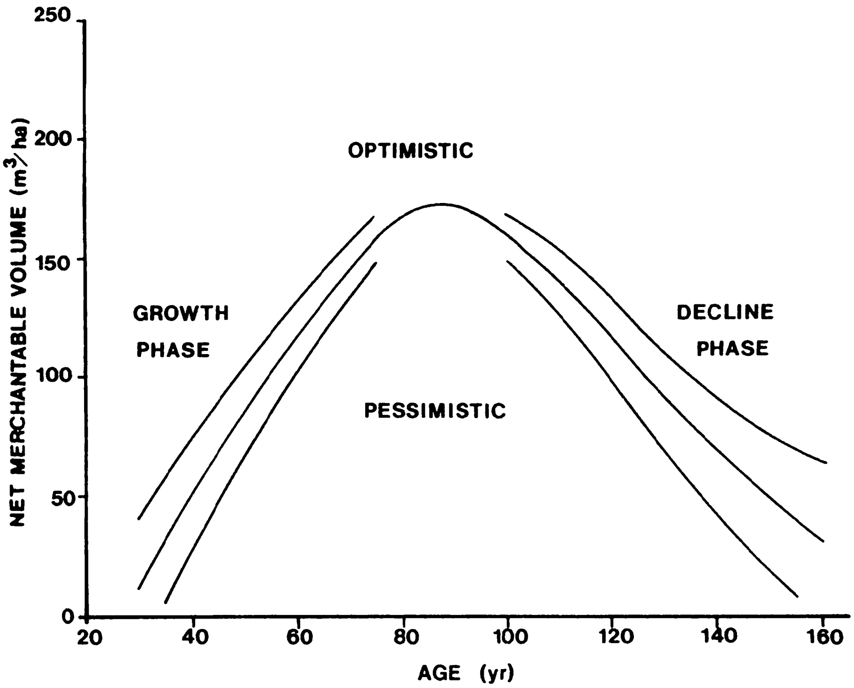

Figure 10. Potential impact of different harvesting strategies on the long-term sustained yield/forest management budget relationship.

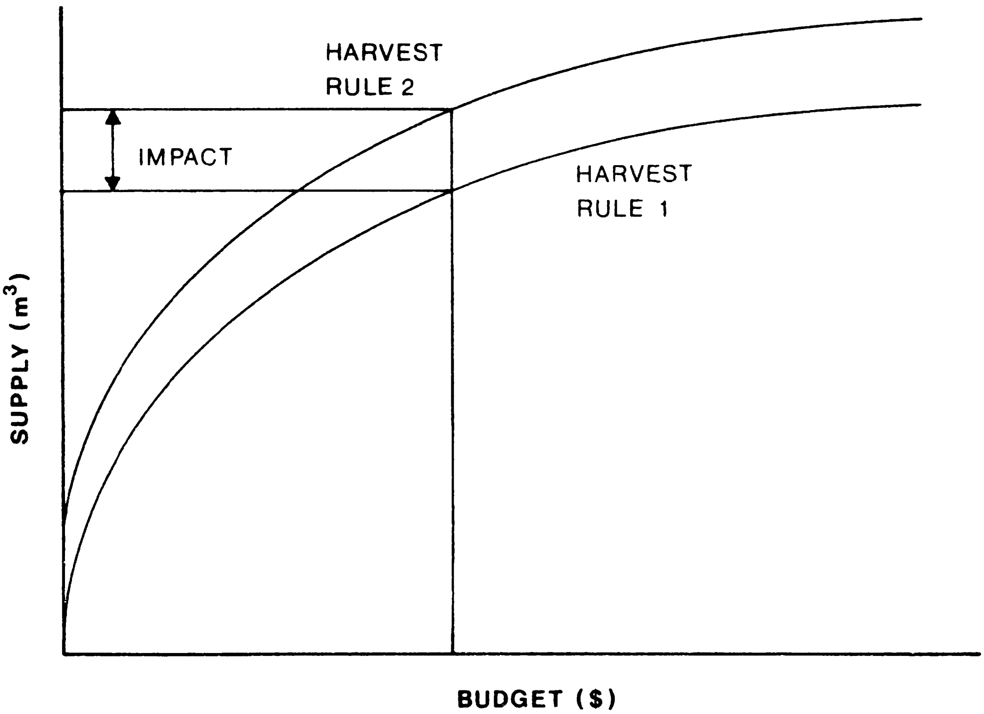

Figure 11. Uncertainty associated with the yield curves used in the NORMAN model. The critical phases of the yield curves will be manipulated to determine the sensitivity of wood supply to yield assumptions.

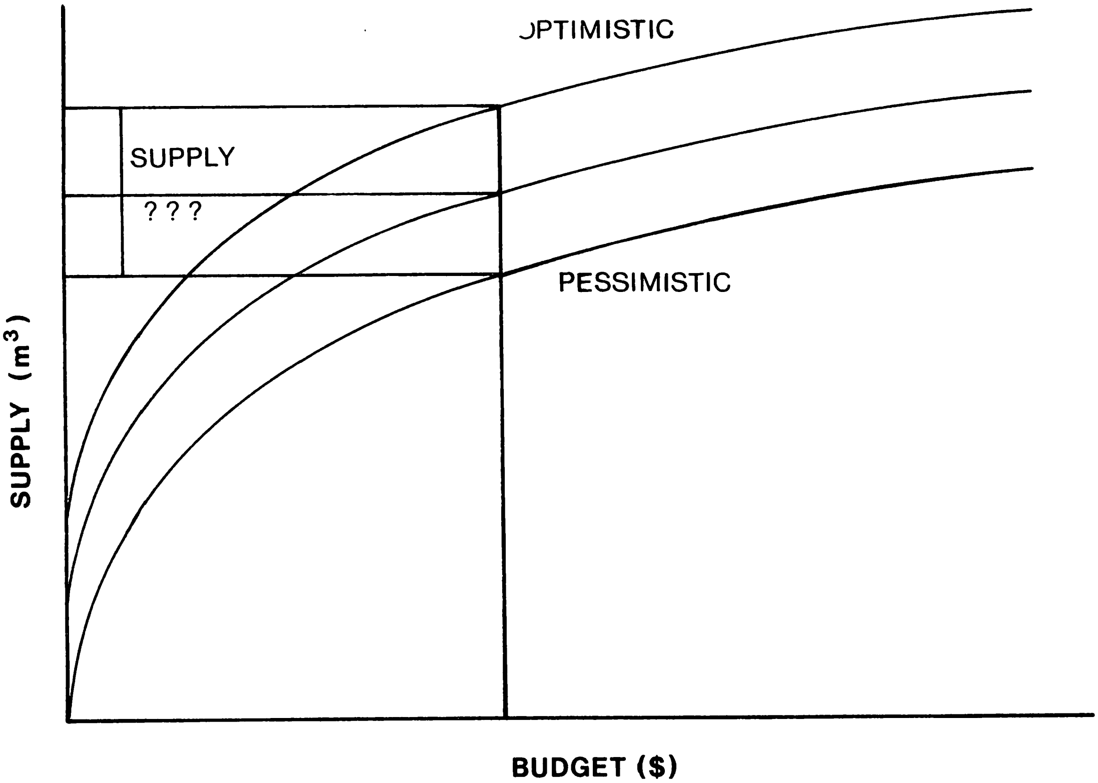

Figure 12. Uncertainty associated with growth and yield leads to an uncertain wood supply for a given forest management budget. Sensitivity analysis will be performed to determine the growth and yield assumptions to which wood supply is most sensitive.

SUMMARY

The NORMAN model being developed in the Northern Region uses the FRI, data base management applications and a modified FORMAN model to simulate wood supply. The first version of the NORMAN model, though a crude approximation of wood supply in the region, is nearly complete. However, a number of improvements are necessary to make the model more realistic and more relevant to the management situation in the region. These improvements include the ability to simulate the treatment of "Not-Satisfactorily Regenerated" [sic] (NSR) areas, specification of more management alternatives for each forest ciass, and the incorporation of return-on-investment criteria into the model. Since there are significant demands for hardwood species in the region, the ability to specify production targets for both hardwood and softwood species within the model must be included. Improvements will also have to be made in the area of FRI updating and in our growth and yield models.

The NORMAN model will be used to estimate the wood supply that is feasible with the current forest management budget. Various management alternatives will be simulated in an attempt to identify how our limited budget should be spent to maximize wood supply in the region. Finally, the model will be used to measure the impact on wood supply of adjustments in the forest management budget and to identify areas in which information is required to improve management.

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PRIME SITE MANAGEMENT: CHASING THE RAINBOW

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Abstract--Prime site management consists of directing forest land management decisions to achieve the highest overall return on investment. Implementation is constrained, however, by misunderstanding, lack of definition of the concept, and the belief that "perfect information" and expensive systems are essential to the program. A "bias for action" plan that will develop and transfer simple, objective forest management tools to the field is suggested. If local knowledge can be improved by developing management accountability at the unit level, objective forest management (i.e., prime site management) will become the norm.

Résumé--Un bon aménagement forestier consiste à orienter les décisions d'aménagement de façon à tirer globalement un rendement maximal du capital investi. Dans la pratique, toutefois, une mauvaise interprétation, l'absence de définition du concept et la croyance qu'une "information parfaite" et des systèmes coûteux sont essentiels constituent des obstacles. Un plan "base d'action" pour la mise au point et la diffusion d'outils simples et objectifs de gestion des forêts est proposé. Si l'on pouvait améliorer les connaissances à l'échelle locale en développant la responsabilité de gestion à cette échelle, un aménagement forestier objectif deviendrait la norme.

When Ron Calvert (Regional Forester, OMNR) asked me to speak about constraints on implementing prime site management, my initial reaction was to refuse! Having been away from Ontario for the past six years, I didn't believe that I was qualified to speak about one of the province's new technological initiatives. Furthermore, as manager of the Ontario Ministry of Natural Resources' (OMNR) newest technology development unit, I didn't like to be negative about new ideas. After some reflection, I decided that perhaps I **was** qualified to speak, inasmuch as my former employer, Canadian Forest Products Ltd. (CANFOR), practised a simple but effective form of prime site management for over 40 years in the Nimpkish Valley (British Columbia), and this practice helped save the company in the great recession of 1982-1987. I shall discuss that briefly later, but first I have a couple of questions for you, the audience.

How many of you understand the term **prime site management?** How many of you believe that prime site management is being practised in Ontario today? How many of you believe that the technology for prime site management has not been developed and is preventing the implementation of an effective prime site program?

On the basis of this informal poll, I would say that the philosophy of prime site management is not well known, nor is it widely practised.

Prime site is defined as the directing of forest land management decisions in accordance with the highest overall return on investment. Prime site management is changing forestry from an art to an objective management system. It provides a rational basis for investment.

Questions arise immediately about this definition:

1) Whose return on investment do we mean: that of OMNR or that of the forest industry? If that of OMNR, are we using value added to the provincial economy or are we using stumpage as calculated benefits? If that of industry, are we calculating present net worth of net revenue produced or minimization of future harvesting costs? These are only a few examples of economic parameters, but each will define very different crop strategies.

2) What is the scope of our activities--are we determining the optimum system of prime site management at the provincial or local unit level?

3) Are we evaluating return on investment for the fiber resource only or are wildlife and recreational values part of the equation?

The first constraint on implementation of prime site management is the lack of clarity of the definition of prime site management and the lack of understanding of the term. Could we be presenting our forest managers with what Baskerville calls "boiler plate" words that may sound good to the nontechnical reader but convey absolutely nothing of substance (Baskerville 1986)?

Let's assume that those involved in prime site management are dealing with the local management units and that quantifiable return on investment has been determined. Another problem in dealing with economic values is the continual fluctuation of markets and revenues. For example, if your company has designated your woodlands a profit center (as is common in British Columbia) and wood is sold to the mills at a fluctuating price based on pulp or lumber prices, obviously prices and/or revenues will rise and fall annually, influencing and possibly changing investment strategies and silvicultural practices.

The second constraint is fluctuation of the economic factors that form the basis of prime site management, as a result of which decision making becomes a very dynamic process, somewhat like chasing a rainbow. The pot of gold consists in maximizing return on investment; therefore, it is difficult to pin down the best rate of return.

Dynamic management of prime sites has necessitated regional strategies for chasing this rainbow. To catch the pot of gold, most believe that a computerized data base that will answer every possible query about the land base and about optimizing the return on our investment is needed. This objective management system will also give the accountants a paper trail along which they can monitor our decisions.

For example, the North Central and Northwestern regions have a plan entitled **A Strategy for the Acquisition of Prime Site Information: The Development of a Dynamic Forest Management Support System** (Towill and White 1987). This plan has five major components with which one must deal before reaching the pot of gold.

Component #1 - Develop criteria to categorize prime, intermediate and non-prime land for the growth of commercial tree species.

Component #2 - Test and adapt existing land resource information to produce prime-land maps.

Component #3 - Complete a soils inventory at the 1:50:000 scale for operational planning.

Component #4 - Develop and link productivity and silvicultural interpretations to land classifications to aid in silvicultural decision making.

Component #5 - Develop a dynamic forest management support model as a link with the resource data base and as a means of facilitating prime site management, and determine if the best rate of return is being achieved.

At component 5, we finally reach the pot of gold, and have the basis for good decision making.

In summary, the North Central and Northwestern regions are proposing an intensive soil survey, prime-land mapping, operational Geographic Information System (GIS) and the development of quantifiable relationships between soils/ecological site types and land productivity. Originally all of this was to cost $4 million over five years. After part of component 2 had been completed and it was found that the Northern Ontario Engineering Geological Terrain Study base maps were not suitable (Robinson, Merrit and DeVries Ltd.), estimates for implementation rose to $8 million[1]. This

[1] Towill, W.D. 1988. Mixedwood Program Forester, Ontario Ministry of Natural Resources, Northwestern Ontario Forest Technology Development Unit, Thunder Bay, Ont. (pers comm.)

program must be completed before prime site management is implemented in the Northwestern and North Central regions.

You probably thought that I would cover the constraints associated with implementing this ultimate system, complete with bells and whistles, especially the problem of funding the system. Paradoxically, however, we ourselves constitute the biggest road block in the way of implementing prime site management. We believe that computerization of the data base and elaborate data bases and analyses as outlined above are necessary for such implementation.

The third and most important constraint of all is the belief that prime site management cannot begin until a perfect inventory and retrieval system has been developed. Unfortunately, such a system is years and millions of dollars away.

The term **prime site management** may simply be jargon which, unfortunately, tends to mask the art of objective forest management that some of us have practised for years. Ironically, this jargon was developed to try to increase the awareness of the need to practise such objective forestry.

A good forester who knows his local conditions usually spends most funds on regenerating brushy productive sites that are accessible by road. This hasn't always been the case, not because of lack of desire, but because of lack of technology to carry out such treatments. For example, the treatment of non-alder brushy sites, in many cases the best of our prime sites, was not possible before the herbicide Vision was registered in 1984. Older brushy stands that did not benefit from Vision treatments are now mixedwood stands, and we really don't know how to manage these.

A company forester commented recently that one of the major problems is lack of information needed to formulate effective strategies for prime site management. Managed-stand yield tables, soil surveys and cost factors for harvesting are needed.

Despite the lack of information, I believe that a basic prime site or crop management system can be implemented with Forest Resource Inventory (FRI) maps, good precut evaluations (these are law in British Columbia), a local site classification system, good knowledge of local economic conditions (i.e., assured wood costs and revenues), Plonski's or local yield curves and a good understanding of cost-effective silvicultural treatments. Some crop strategy assessment techniques are outlined in a recent report entitled **Establishing spacing regimes and rotations for coniferous species--a northern Ontario case study** (Willcocks et al. 1989).

The fourth constraint is that the technology to carry out effective management on some productive sites close to the mill has not been developed.

The fifth constraint is an unwillingness to make assumptions or to use existing knowledge about cost, yield values and other management factors to permit the establishment of a basic objective or prime site management system.

If we are willing to make assumptions and to use existing knowledge, we are doing what Peters and Waterman (1981) in their best-seller **In search of excellence** called a bias for action, a preference for doing something--anything--rather than sending questions through cycles and cycles of analysis and committee reports.

Far be it from me, the manager of a technology development unit, to suggest that a simplified system of prime site management is the optimum system for forest managers, and I certainly would not suggest that one system is good for all managers, but it is a start, a framework upon which we can build. Improvements in site-specific analysis tools such as forest ecosystem classification, precut survey technology, and site productivity information are essential if we are to make better approximations of the return on our investments.

Pilot GIS projects based on prime-land inventories, such as those under way in Kirkland Lake District, must be developed and scrutinized closely. The broad application of the "bells and whistles" technology will be much easier if simple crop planning and/or prime site systems, usually based on existing technology, are widespread.

The irony of this whole exercise is that we are trying to implement cost-effective forest management by objective systems such as prime site management, but our approach to implementation is far from cost-effective because we lack direction. This absence of direction is evident because no policy based on field and administrative input and outlining measurable goals for prime site management is in place. As far as I know, no group is working on such a policy at the present time, although I believe that this will soon change.

The sixth constraint is the lack of effective provincial leadership in prime site management. Possibly a prime site management system could be developed through the technology development units in close cooperation with their respective regions. Leadership doesn't mean the "top down" approach that Baskerville (1986) referred to as being responsible for "a general absence of creativity". Field foresters, both provincial and industrial, must be intimately involved in the development of prime site management.

What about CANFOR's prime site management in the Nimpkish Valley? This system consisted 30 years ago, as it does now, of identifying the best sites by forest inventory and local knowledge and assuming conservative but reasonable MAI values for the second-growth forests. Forestry staff did precut surveys by cruising these stands. The company set an objective to maintain a consistent log mix from its limits, thereby assuring a relatively consistent annual revenue. They patch cut along their expensive road systems and retained accessible old-growth inventory for subsequent years. They also balanced their cut between the poorer-quality higher-elevation sites where snow was a hindrance to harvesting, and the prime land in the valley bottoms and on the lower slopes. The valleys were not liquidated but were logged over 30 to 40 years instead of four.

Investment in expensive plantations was restricted to the valley bottoms and rich lower slopes, other more inaccessible areas being left for natural regeneration and longer rotations. Silvicultural investments for each block were at company expense and were evaluated on the basis of a net profit calculation (dollars/m^3 net profit generated per mean annual increment produced as a result of this investment).

The result of this simple form of management was year-round logging (not common on Vancouver Island), an experienced, steady work force, and full use of capital investment.

In 1984, the company had serious financial problems, but cutting of some accessible, high-value timber reserves permitted a significant increase in revenues. Capital road costs were also reduced since these stands were along existing roads and wood costs were therefore lower. A skilled, dependable work force also lowered costs, so that there was an overall significant increase in net profits.

The Nimpkish Valley still has at least 30 years' worth of high-value, old-growth wood and 20- or 30-year-old accessible, intensively managed plantations that will produce 800 m^3/ha of sawlogs 60 cm in diameter when the old growth is depleted.

CANFOR got its first personal computer only a few years ago, and is now considering the purchase of GIS technology. This new technology will not mark the beginning of prime site management, but possibly it will be an improvement on the system already in use.

CANFOR's success was centered on excellent knowledge of the valley's sites, which was based on the long experience of their foresters, and on its clear understanding of accountability. Work on tree farm licence no. 37 was clearly the responsibility of the company and in many cases was funded by it. In Ontario, such a situation generally doesn't exist.

The seventh constraint is that responsibility is not well defined, and there is no system of accountability. Consequently, there is no rationale for forest investments. As Baskerville (1986) stated:

> "The responsibility for quality of management plans in OMNR is dispersed, perhaps to the degree that, where everyone is responsible, no one is responsible."

Baskerville also states that unit foresters are not staying in their units long enough to provide stability and to gain the understanding of the local resource that is essential for the design and implementation of a good forest management system.

The eighth constraint is that local knowledge of forest management units in Ontario is lacking because of the rapid turnover of management foresters, and this situation may force us into relying on computerized data-base decision-making systems.

The essence of my argument is that implementation of a prime site management system is being constrained mostly by misunderstanding of the concept, by myths about the need for complete information and expensive implementation systems, by lack of leadership needed to catalyze participation by field foresters, and by the general lack of accountability for forest management decisions.

Although objective forest management is being practised in Ontario, it is not the norm, and if we continue to chase the rainbow we may never reach our goals (Fig. 1).

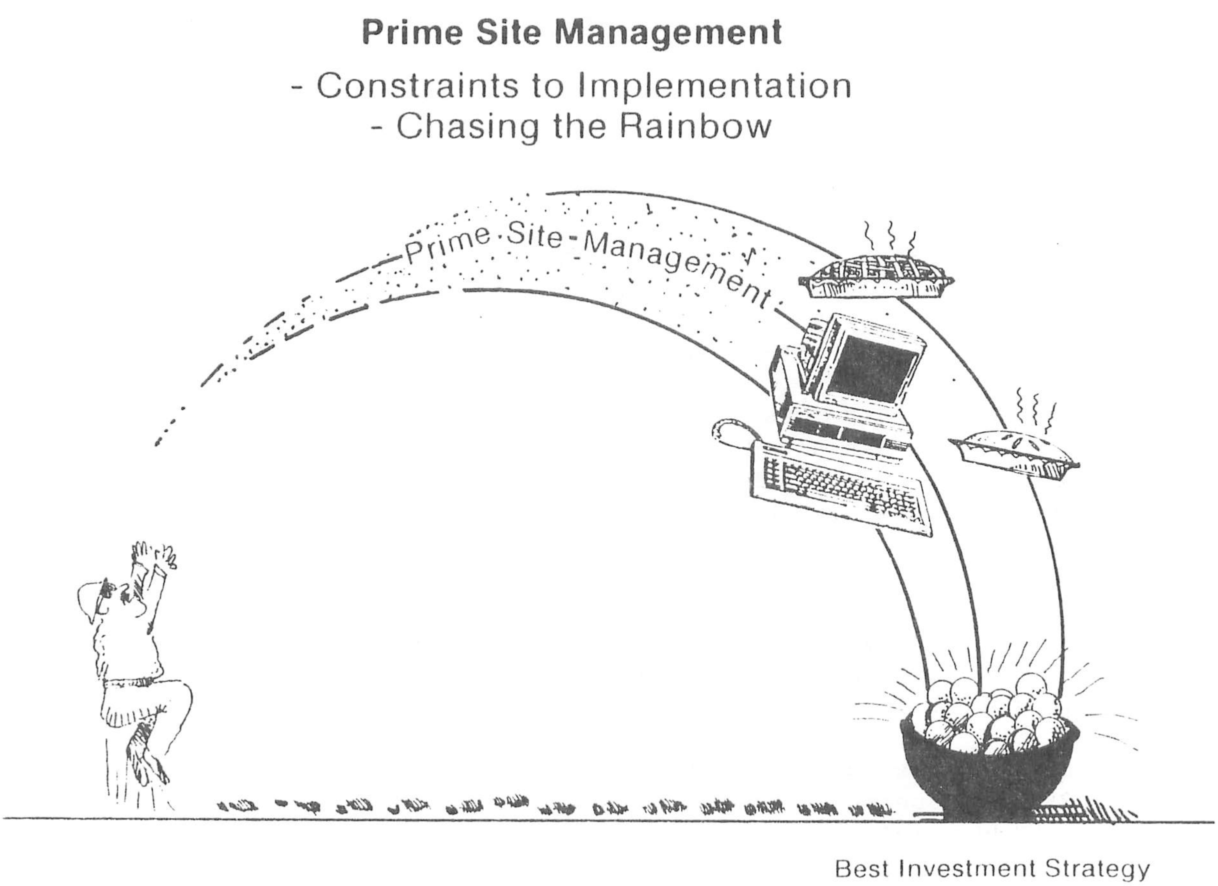

Figure 1. Chasing the rainbow.

If, instead, we implement a "bias for action" that will develop and transfer simple, objective forest management tools to the field, and if we can improve local knowledge by developing continuity of management as well as accountability at the unit level, we will be able to build a basic management framework, and objective forest management will become the norm.

Computerized retrieval of complex data bases is a thing of the future and steady progress in this area is certainly desirable and necessary, but a simple, rational, decision-making framework also needs to be firmly in place. Remember, the first men in space used simple rockets before they built and operated the space shuttle. Why don't we build a simple, rational, decision-making model before we chase the rainbow too far?

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ECONOMIC DECISION MAKING FOR PRIME SITES:

THE LINK BETWEEN FOREST MANAGEMENT AND ROAD BUILDING

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Abstract.--The Ontario Ministry of Natural Resources has expressed interest in moving to a management program based on prime sites. At present, however, there is no consensus about how prime sites will be selected and identified. A prime site management program should be guided by the economic performance of different levels of investment on various sites. This paper outlines the general process of classifying sites by economic potential as used in a case study, and discusses some of the study findings about the interactions between forest management capability and road building.

Résumé.--Le ministère des Richesses naturelles de l'Ontario s'est montré intéressé à adopter un programme de gestion basé sur les sites prioritaires. À l'heure actuelle, toutefois, il n'y a aucun consensus sur la façon dont ces sites prioritaires doivent être choisis et identifiés. Un programme de gestion des sites prioritaires devrait se baser sur le rendement économique de divers niveaux d'investissements en divers endroits. Cet article décrit le processus général de classification des sites en fonction de leur potentiel économique tel qu'utilisé dans une étude de cas, et analyse certains des résultats portant sur les interactions entre les capacités d'aménagement forestier et l'aménagement de routes.

INTRODUCTION

There was a young forester from Timmins,
Who was a disciple of Kimmins,
From oldest first he departed,
And on prime site he started,
By sorting out thick trees from thin.

This may be one way to identify prime sites, but there is more to it than separating the thick trees from the thin ones. That prime site management (PSM) looks beyond the biological capability of land is, I think, widely understood and accepted.

In fact, PSM is a marriage of physical and economic potential. The definition of PSM prepared by the Ontario Ministry of Natural Resources' (OMNR) Prime Site Management Steering Committee makes this clear: PSM is "the directing of forest land management efforts in accordance with the highest overall return in [sic] investment" (Anon. 1987).

The general idea is to tally up the benefits that come from managing each stand, or rather land unit, tally the associated costs, and then rank land units by their financial productivity. The most valuable lands are prime sites.

Biological considerations are half of the picture, but only half. Physical vigor influences the quantity of products produced, but not their value. Land type and biology circumscribe the range of establishment options, but the costs of site preparation, planting, seeding, and tending are economic parameters. The length of time to harvest depends in part on the innate productivities of species and site; the practice of discounting permits the comparison of values established and different times.

There is a pattern here: each biological attribute is paired with an associated economic attribute. They are as inseparable as Siamese twins.

In the past, forest managers were concerned primarily with the biological aspects of management. Now values and costs are drawing attention. To adopt a prime site orientation would accelerate this trend.

Why might we wish to adopt PSM? How would our current approach to management change under PSM, if at all? As the PSM Steering Committee observed, "everybody's doing it **but** few agree on **what** they're doing or **why** they're doing it" (their emphasis).

Let me present to you the results of a study that sheds some light on these questions (Williams 1987). The motivation for this study came from Fern Miller and Ken Armson, but the views expressed in the report are my own. This study also benefited from the gracious cooperation of staff of the Spruce Falls Power and Paper Company and other OMNR staff.

The project was designed to stimulate road building and harvest activity according to four hypothetical harvest scheduling approaches. The Ontario Wood Supply and Forest Production (OWOSFOP) computer program was altered to run on a stand-by-stand basis on a yearly cycle. The allowable cut was calculated on an area basis and updated every five years. Harvest allocation options were as follows:

i) oldest first
ii) minimum sufficient road extension
iii) preferred sites
iv) minimum opportunity cost.

The "oldest-first" rule was simulated by ranking accessible stands by age and harvesting the oldest stands down to a given "old-age level".

The preferred sites option was intended to approximate a prime sites strategy. Because of insufficient information, genuine prime sites could not be identified. In this option a set percentage of the allowable cut was taken from preferred sites older than the minimum harvest age. This lower harvest age limit was set at 80 years, and applied throughout the study. The remainder of the cut was taken on an oldest-first basis from non-preferred stands.

The minimum sufficient road extension and opportunity cost cases were described in Williams (1987) and are of minor relevance here.

The Gordon Cosens Forest near Kapuskasing, Ontario served as the study area. It was divided into five regions, largely on the basis of current stand condition. Existing and proposed roads were mapped, a road structure was assumed in the remaining inaccessible areas, and the kilometre-long road segment that would provide access to each stand was identified. Each simulation year, the model would be used to determine if the specified allowable cut could be obtained from accessible stands and, if not, all roads would be extended by 1 km. The test-and-build sequence would be repeated until the cut could be made. Road construction and maintenance costs were obtained from the Forest Management Agreement (FMA) ground rules and discounted to the initial simulation year. "Road-building delay periods" (i.e., periods during which road building in a region was assumed not to occur) were applied to regions with younger stands, in an effort to improve on the assumption that road construction would be unit-wide each year.

All stands were separated into upland, lowland, and jack pine categories. This was done because it was felt that the three forest types could be identified from the Forest Resources Inventory (FRI) and that this breakdown was more informative than FRI site class about the stand establishment procedures that would be followed and the nature of the subsequent forest.

The jack pine site type had at least 50% jack pine and turned out to be of little significance. Other sites with 90 or 100% conifer cover were judged to be lowland sites, while stands with 20 to 100% hardwood cover were assumed to be on uplands.

All stands of pre-1972 origin were assumed to be unmanaged. The amount of management that an upland cutover would receive was based on the softwood:hardwood ratio in the original stand. Since it is difficult to raise the conifer component in the succeeding stand, pure hardwood stands were left unmanaged, those with 70-90% hardwood were managed at a moderate intensity, and those with 20-60% hardwood were managed intensively and returned to predominantly softwood.

The lowland stands were also subdivided. Factors such as depth to water table, organic soil depth and peat type influence management on lowland sites, but these site features are not picked up by the FRI. Therefore, I returned to the FRI and assumed that stands on sites of classes X and 1 would be intensively managed, while those on sites of classes 2 and 3 would receive extensive management.

The area in each stand type is shown in Table 1.

Table 1. Distribution of management unit area by site type

Site type	Area (ha)	Percentage
Unmanaged upland	44,515	4.8
Mixedwood upland	106,582	11.5
Spruce upland	209,986	22.7
Unmanaged lowland	279,599	30.2
Managed lowland	268,122	28.9
Jack pine	17,641	1.9

Yield curves for each of the six forest types were estimated from Plonski (1981), Smith (1983), an OMNR research note (Anon. 1982) and company information.

Preferred sites were selected by identifying the revenues and costs associated with each site type and calculating the annuity equivalent to the net return from management on each site (see Table 2). Softwood was assumed to be pulped, producing a gross revenue of $\$200/m^3$. Hardwoods were accorded no value. The discount rate was taken to be 3% without inflation. The two most valuable site types, spruce upland and managed lowland, were designated as prime.

Table 2. Equivalent annuities by site type

Site type	Equivalent annuities ($/ha)
Unmanaged upland	42.70
Mixedwood upland	60.55
Spruce upland	119.40
Unmanaged lowland	36.52
Managed lowland	81.06
Jack pine	76.90

The simulation period lasted 60 years. Total volume cut, total discounted road cost, discounted road cost/m^3 cut, average harvest volume/ha, and proportion of lowland in the overall cut were recorded for each simulation. It quickly became evident that the simulation results could not be explained without reference to the age class structure of the management unit.

Figure 1 shows that the Gordon Cosens Forest is overmature, with a sizable chunk of recent cutover and insufficiently regenerated lands. The right bar in each age class is the area of lowland and the left bar measures upland. The age class structures of the upland and lowland sites proved dissimilar.

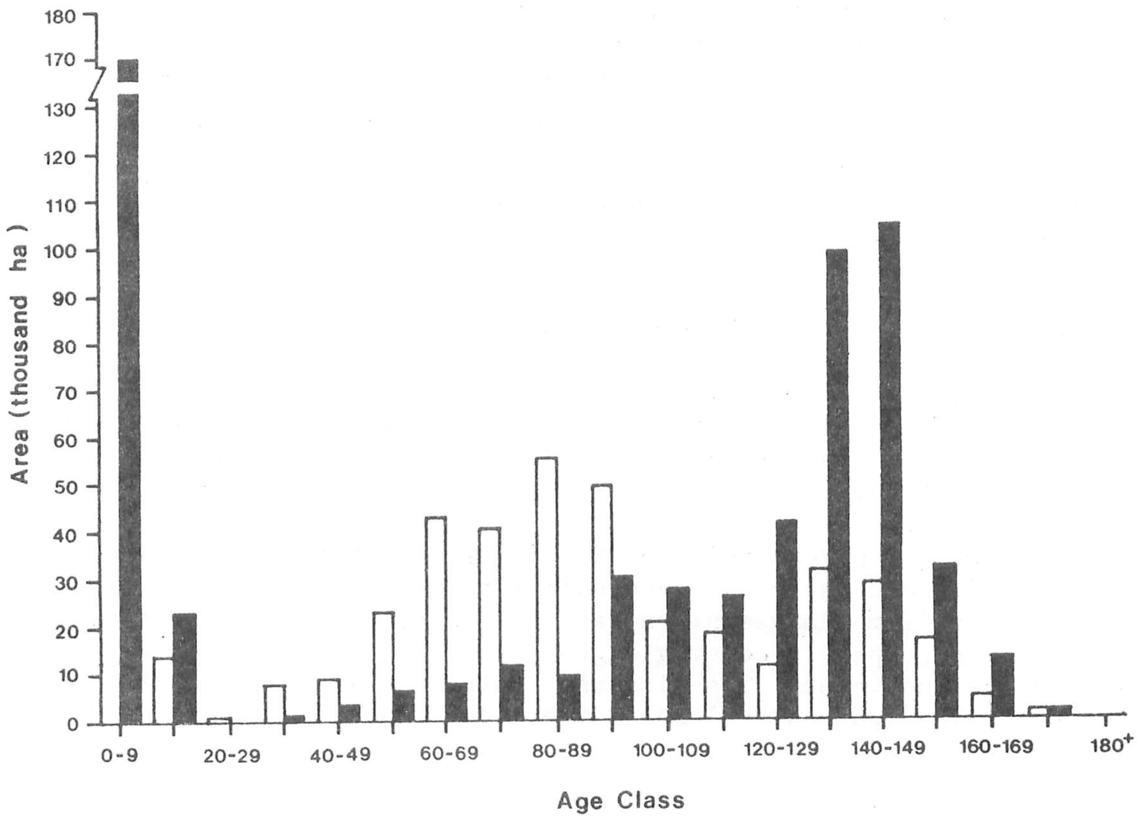

Figure 1. Age-class structure of the Gordon Cosens Forest.

SIMULATION RESULTS

The outcomes of the "oldest-first" and "preferred sites" simulations will be explained in some detail. Next, representative runs from all four options will be compared briefly. This will allow me to infer how PSM may differ from what we are doing now, and how it may perform in comparison with other forest management options. I will conclude by identifying conclusions that pertain to PSM, and are not just study-specific.

Oldest First

Three "oldest-first" runs, distinguished by the minimum age of the "oldest" stands, are summarized in Table 3. In each case, at least 70% of the cut came from the "oldest" stands.

Table 3. Description and summary of three oldest-first runs

Run no.	Minimum age of old stands	Total harvest ('000 m^3)	Total road cost ('000 $)	Discounted road cost ($/$m^3$)	Harvest volume (m^3/ha)	Percentage of lowland cut
1	120	80.6	92.8	1.15	142.87	53
2	140	77.0	111.3	1.45	136.82	61
3	150	55.6	140.2	2.57	124.39	72

These summaries show that total road costs, road costs/m^3 of wood harvested and concentration of harvest in lowlands increased as the harvest was taken from older stands. At the same time, the volume harvested/ha declined. The strictest application of the "oldest-first" rule could provide the required harvest for only 48 years.

As "oldest first" is applied more strictly, the cut is drawn from a smaller pool of stands and road building must be accelerated. "Up-front" access cost rises steeply. Adding to the cost of wood/m^3 is the lower volume obtained from older stands.

For two reasons there was only a small reduction in total harvest volume when the harvest limit was raised from 120 to 140 years. First, so much of the cut in the initial decades was composed of stands older than 140 years that tightening the restriction had little effect. Second, as the restriction was tightened, a higher proportion of lowland was cut. "Unmanaged" lowland stands had more volume than upland stands and added volume until age 130.

Preferred Sites

Harvesting in the preferred-sites option was based on the requirement that these site types provide a certain percentage of the harvest area. If there was more accessible preferred area than was required to meet the cut specifications, an equal proportion of each accessible preferred site was cut. Thus, all accessible preferred sites older than 80 years were cut each year.

Preferred sites constituted 51.6% of the management unit area and could not supply much more than this proportion of the cut over one rotation. Indeed, when 70, 75 and 80% of the cut were drawn from preferred sites, the simulations broke down after 59, 55, and 52 years, respectively. The results of six sample runs are shown in Table 4.

Table 4. Description and summary of six preferred-site runs

Run no.	Cut from preferred sites	Total harvest ('000 m^3)	Total road cost ('000 $)	Discounted road cost ($/$m^3$)	Harvest volume (m^3/ha)	Percentage of lowland cut
8	50	75.7	79.7	1.05	138.02	53
9	60	75.9	83.3	1.10	133.72	54
10	65	74.4	88.8	1.19	131.46	58
11	70	71.6	93.1	1.30	128.86	62
12	75	65.3	97.1	1.49	126.59	63
13	80	62.6	101.2	1.62	126.01	61

What is surprising is that the overall harvest and volume/ha declined as preferred sites were favored because older stands with lower volumes were taken in the oldest-first portion. As one would expect, more emphasis on preferred sites raised the present value of road costs. The location of harvest was influenced by both the target and the non-target portion of the cut. Lowland sites made up just over 50% of the preferred sites and a larger portion of the non-preferred sites. Therefore, increased harvesting on preferred sites meant that more of this portion of the cut was taken from lower-yielding upland stands. However, more lowland was cut in the non-preferred part of the cut and the net effect was that more lowland was cut as preferred sites were relied on more heavily.

Comparison of Different Options

Three attributes of the simulation outcomes were selected as being of major importance: the total volume cut, the discounted road cost/m^3, and the evenness of harvest volume flow. Unfortunately, the simulations did not permit adequate appraisal of the condition of the forest at the end of the simulation, a fourth important quality.

Figure 2 shows the total volumes cut in a selection of runs. Perhaps the most striking feature is their relative uniformity, especially when allowances are made for runs that lasted less than the full 60 years.

With this result, the significant differences in road cost/m^3 were due primarily to varying total road costs (see Fig. 3). The minimum roads case lived up to its name. In other options, there was a tendency for road costs to rise as the allowable cut specifications became narrow, or as a given set of stands was required to make up more of the cut.

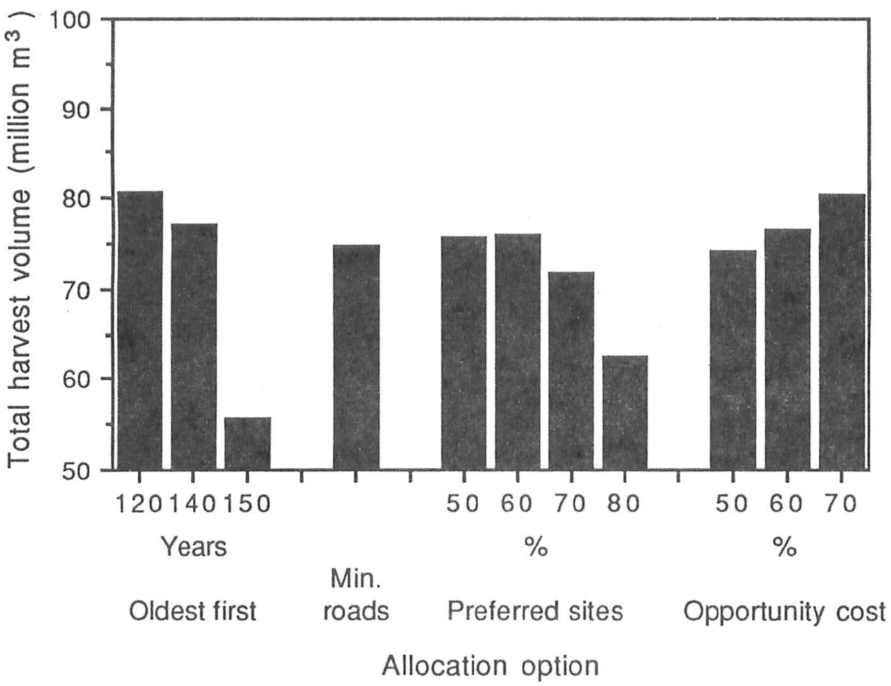

Figure 2. Total harvest volume for each scenario.

The annual harvest volumes from run No. 1 are plotted in Figure 4. The large sawteeth occurred mainly because inventoried stand ages tend to be divisible by 10. The harvest declined throughout the first 25 years as the large area of old lowland deteriorated. After remaining low for another decade, the harvest level increased again. All options showed the same general pattern. However, the variation in harvest levels was not often this pronounced.

Figure 5 shows that the year-to-year timber flow was smoother in the case of 60% preferred sites (Run No. 9), largely because of the willingness of woods operators to cut preferred sites once they reached 80 years and the scarcity of young stands. Also, the volume flow was more uniform throughout the simulation.

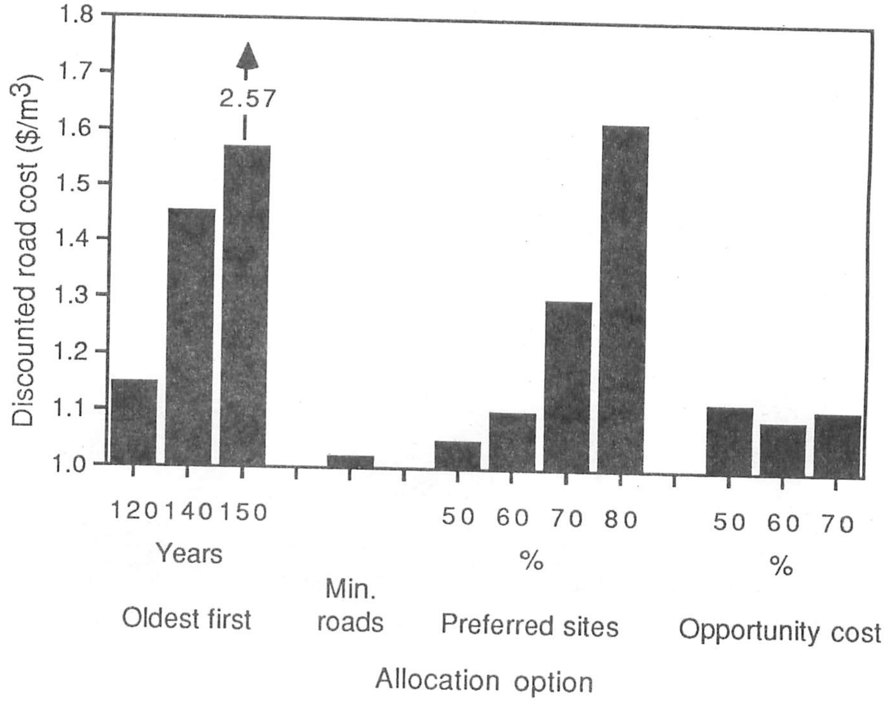

Figure 3. Discounted road cost per m^3 of wood harvested in each scenario.

The construction of some harvest rules stabilizes the character of the annual cut in terms of the average harvest age and type of site cut each year. Consequently, a similar outcome can be obtained over a range of specific schedules of a rule type, and over a range of management unit conditions.

The "oldest-first" rule was relatively unstable, since it had only a lower age limit and no direct control over stand type. The "preferred site" option was somewhat better, since the mix of sites was partially predetermined. However, the average age of harvest was restricted only by the minimum allowable cut age. In these options, the average age of harvest increased until year 45 as the overmature lowland bulge worked its way through. The most stable annual cut was obtained when upper and lower age limits were imposed (in the "opportunity cost" option).

CONCLUSIONS

The study clearly shows the strong interdependence of the characteristics of the stands in the management unit, the harvest, the access requirements and the harvest rule chosen. Adoption of PSM will have an effect on the forest, the cut, and the road network. Equally, the forest, roads, and landbase will affect the performance of PSM.

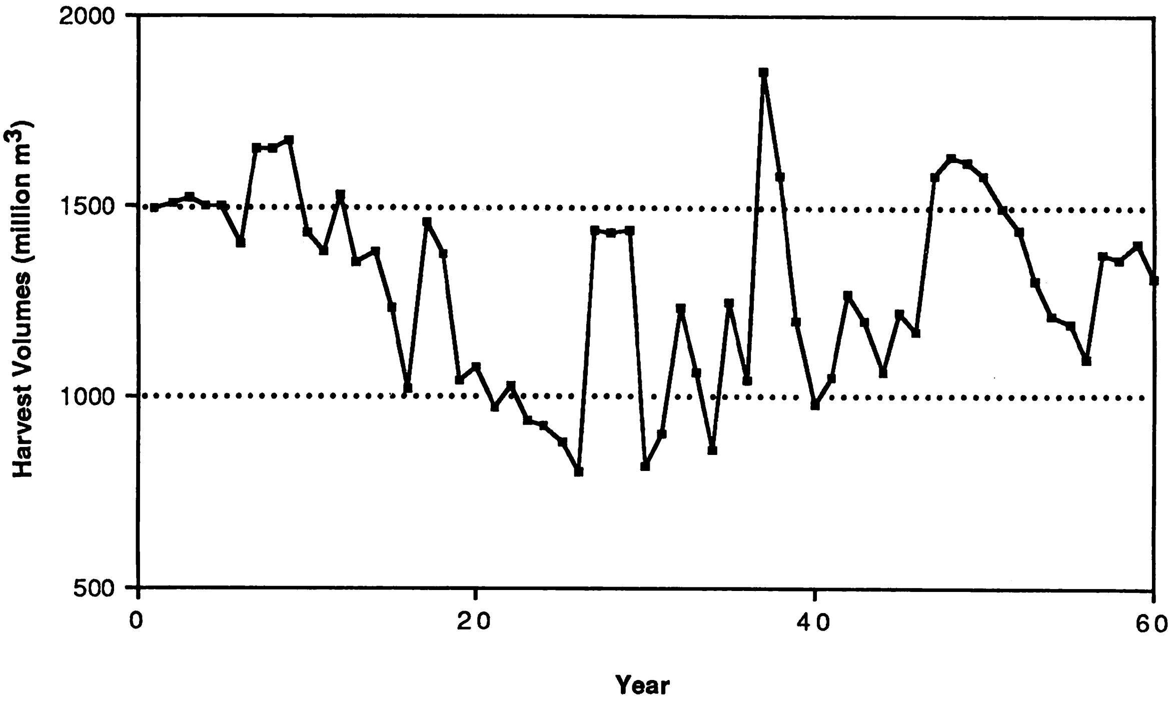

Figure 4. Annual harvest volumes as a result of the oldest first scenario, 70% cut of trees older than 140 years.

This is the second conclusion--that the benefits of PSM will vary from management unit to management unit. The prime area available at any one time depends on the landbase and the forest. Prime sites must be chosen and managed within these constraints. If one wishes to extract the most from PSM, one may vary the choice of prime sites between management units, even adjacent ones. It will be challenging to develop efficient ways of implementing PSM on a local basis.

As emphasis is placed on harvesting prime sites, or as prime sites are chosen more selectively, more access must be provided. The exact cost will depend on how prime sites are distributed with respect to the existing road network.

The benefits of PSM may not become apparent until the new forest is harvested. Such was the case in this study, in terms of both volume cut/ha and forest-wide yield. However, there are two points to be kept in mind. This study was not designed to examine the pros and cons of PSM, and factors such as silvicultural expenditures were not monitored. Also, the outcome will be specific to each management unit.

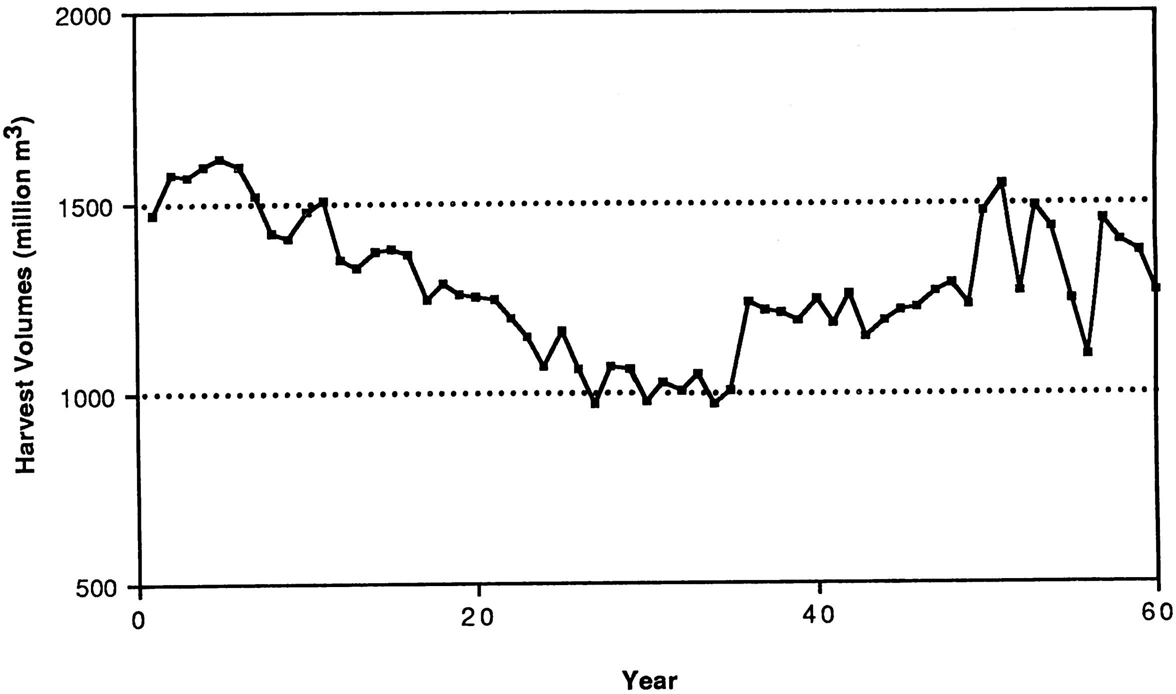

Figure 5. Annual harvest volumes as a result of the preferred site scenario, with a 60% cut.

Finally, where harvests in overmature management units, such as the Gordon Cosens Forest, are scheduled by some version of the "oldest-first" approach, adoption of PSM will limit the losses that occur because the "oldest-first" rule ensures that harvesting will be centered in decadent, low-volume stands.

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SESSION IV: Multiple-use -- Impact on Wildlife

APPLICATION OF THE MOOSE AND DEER HABITAT GUIDELINES: IMPACT ON INVESTMENT

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Abstract--The province of Ontario meets the habitat needs of northern Ontario wildlife species by applying the moose or deer habitat guidelines during timber management. The implementation of these guidelines often results in higher investment levels. The issues surrounding the application of these guidelines are presented and possible solutions are discussed.

Résumé--La province d'Ontario veille aux besoins de la faune du nord de l'Ontario en formulant des directives sur l'habitat de l'orignal et du cerf s'appliquant en gestion forestière. Souvent, par suite de l'application de ces directives, les investissements nécessaires deviennent plus considérables. On analyse les divers aspects de cette question ainsi que les différentes solutions possibles.

INTRODUCTION

The **Timber Management Guidelines for the Provision of Moose Habitat** (Anon. 1988) and the **Summary of Timber Management Guidelines for Providing White-Tailed Deer Habitat** (Anon. 1987) assist resource managers in maintaining or creating, through timber management, the diversity of age classes and species of vegetation that provide habitat for moose (**Alces alces**) and deer (**Odocoileus virginianus**), respectively. These flexible guidelines identify techniques and procedures that may be applied on a site-by-site basis at the discretion of resource managers involved in the planning process.

The diversity of sites, management objectives and resource demands in the Boreal and Great Lakes-St. Lawrence forest regions of Ontario has resulted in a variety of examples of how the guidelines have been applied. At the same time, the growing demand for low-cost wood fiber and for both consumptive and non-consumptive wildlife use has made it more difficult to reach an agreement on application of the guidelines that is satisfactory to both wildlife and timber managers.

The purpose of this paper is to review the intent and application of these habitat guidelines and to discuss the issues they raise in the context of the theme of this symposium, **A Critical Look at Forest Investment.**

THE GUIDELINES AND THEIR APPLICATION

It is the intent of the Ontario Ministry of Natural Resources (OMNR) to meet the habitat needs of the majority of northern Ontario wildlife species by applying the timber management guidelines for moose or deer. This strategy is called **featured-species management.** Featured-species management takes advantage of the generalist nature and large scale of habitat required by these ungulates and assumes that if we manage habitat needs for either moose or deer, we also meet the habitat requirements of a large number of other wildlife species. Moose is the featured species in the boreal forest and white-tailed deer is the featured species over much of the Great Lakes-St. Lawrence forest region. Although moose and deer are featured generally, other wildlife, such as threatened or endangered species, may be featured locally (Euler 1988).

The habitat guidelines for both moose and white-tailed deer approach the subject in two ways: by setting out a) general range requirements of the species and b) specific, geographically defined habitat requirements.

Range management for moose involves maintaining or enhancing moose habitat over large areas by creating a variety and interspersion of forest stand conditions on a scale compatible with moose requirements. Thompson and Euler (1987) identified three scales on which moose habitat is best examined:

1) a broad scale that considers the needs of an entire local population

2) a smaller scale that includes the basic needs of the animals

3) an individual scale that refers to food requirements.

The broad scale is addressed by applying the moose habitat guidelines as a general range management strategy. This means that the guidelines are always applied but the level of flexibility increases as the inherent productivity of the land base decreases. The smaller scales, concerned with the life requirements of individual animals, are addressed by the general application of the guidelines combined with consideration of site-specific factors such as mineral licks, calving areas, aquatic feeding areas or late-winter concentration areas. The details of how and where the guidelines should be applied are described fully elsewhere (Anon. 1987, 1988).

Application of the Guidelines

The rigor with which the moose habitat guidelines are applied varies. This variation is attributed to the personal style and experience of resource managers and to specific site-related objectives. Generally, if cutting has been modified so as to meet the specifications in the guidelines, then they are considered to have been rigorously applied. Conversely, if there has been no modification of the cutting pattern or if the final cut pattern does not conform to specifications, it is felt that the guidelines have not been applied. This perception is faulty, however.

The guidelines are applied in every situation. However, modification of the desired cutting pattern may or may not be necessary, depending on the manager's perception of productivity, land capability, management objectives or other factors.

For example, the 38 vegetation types of the Northwestern Ontario Forest Ecosystem Classification[1] can be assigned to categories that represent distinct values for moose habitat. These habitat values include summer feeding, early-winter food and shelter, late-winter shelter and general-purpose or conditional cover (Fig. 1). These components relate directly to the food, cover and security necessary to sustain the moose population (Timmermann and McNicol 1988).

Summer feeding areas can include a variety of stands ranging from pure deciduous to heavy, conifer-dominated mixedwoods but with an abundant shrub and herb-rich understorey featuring desirable browse species such as aspen (**Populus tremuloides** Michx.), mountain maple (**Acer spicatum** Lam.), willow (**Salix** spp.), balsam fir (**Abies balsamea** [L.] Mill.), beaked hazel (**Corylus cornuta** Marsh.) and mountain-ash (**Sorbus americana** Marsh.). Requirements for shelter are minimal although topography and proximity to aquatic feeding areas or thermoregulation sites often determine utilization. Early-winter areas with moderate conifer composition provide horizontal and vertical cover in varying degrees. Abundant browse of aspen, mountain maple, poplar, willow, balsam fir, mountain-ash and beaked hazel are essential. Heavy post-rut feeding makes moose dependent on the availability of abundant browse until deep snow or cold temperatures restrict use. Late-winter shelter is at its best when there is abundant vertical and horizontal cover and a conifer canopy with good

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1. Sims, R.A., Towill, W.D., Baldwin, K.A., and Wickware, G.M. Northwestern Ontario forest ecosystem classification. (unpubl.)

vertical distribution of branches. Shelter and protection from deep snow are of primary importance but abundant food or food-production capacity nearby enhances the value of this mixedwood habitat in winter as well as in summer.

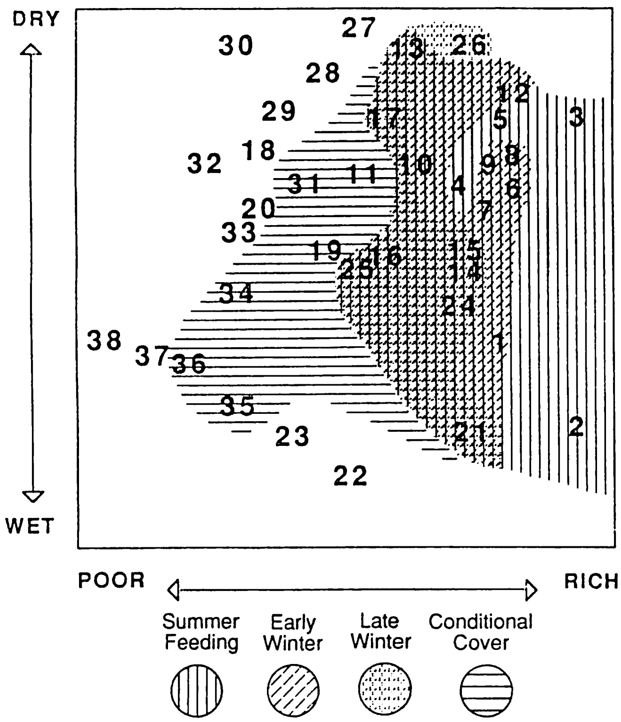

Figure 1. The 38 vegetation types of the Northwestern Ontario Forest Ecosystem Classification display stand attributes that represent various values for moose habitat. The smaller the distance between stand numbers on the ordination, the more similar the stand attributes. All vegetation types represent natural stands of a merchantable age.

Some stands, which we call conditional or general-purpose cover, provide good winter shelter but an inadequate supply of food. Therefore, these stands are of high value only if browse is available in neighboring stands. These stands provide abundant vertical cover and are suitable for moose corridors or reserves in modified-cut areas. The application of the moose habitat guidelines during timber management enhances the value of these stands to moose.

Application of the guidelines is an attempt to **maintain** high-quality habitat by ensuring continuity of the food and cover supply with a reasonable degree of interspersion. Some pure conifer stands, particularly jack pine (**Pinus banksiana** Lamb.) or jack pine-black spruce (**Picea mariana** [Mill.] B.S.P.) mixtures, provide excellent winter cover and summer thermoregulation sites, but very limited food. The application of the guidelines in these areas can **enhance** habitat by creating browse close to cover. Finally, some stand conditions provide neither good shelter nor abundant browse before or after timber harvest. Modified cutting in these stands to increase diversity will not necessarily improve habitat quality for moose. Application of the guidelines in these areas permits the flexibility of larger cutovers, less edge and fewer reserves at the discretion of resource managers.

ISSUES

Five main issues are raised when the application and intent of the moose habitat guidelines are considered for timber management. These issues identify philosophical or logistical problems perceived by managers when wildlife and timber are managed on the same land base.

1) "Normalization": How do we develop the best age structure and stand distribution in the new forest for both wildlife and timber production?

2) Cut Size: What are the minimum and maximum operating block sizes and shapes?

3) Timing: How long must a residual stand be left before a return cut is made?

4) Access: How do we best achieve road access to facilitate timber extraction?

5) "Priorization": Can we establish priorities for land-use activities that are based on land capability?

Normalization

At present, there is an overabundance of old-growth forest, and most of that is located far from the mills (Anon. 1986a). This pattern has resulted from past practices of harvesting the most accessible and cheapest wood first, then expanding the road network. This pattern will be difficult to change without major investment incentives. In essence, we are letting our future be dictated by the mistakes of the past rather than taking positive steps to correct what is now an unbalanced forest. The lack of balance demonstrates itself in the age distribution of stands (Fig. 2 and 3) and in the spatial orientation of those stands. As long as large tracts of timber reach merchantable status at approximately the same time, conflict between the interests of timber management and those of wildlife management can be expected. The tendency is to take large tracts of old forest and over a 5- to 10-year period reduce them to large tracts of young forest. Both situations are less than favorable for moose, deer and many other wildlife species. Conversely, the greater the diversity and distribution of areas ready for harvest the less likelihood there is of conflict over application of the guidelines.

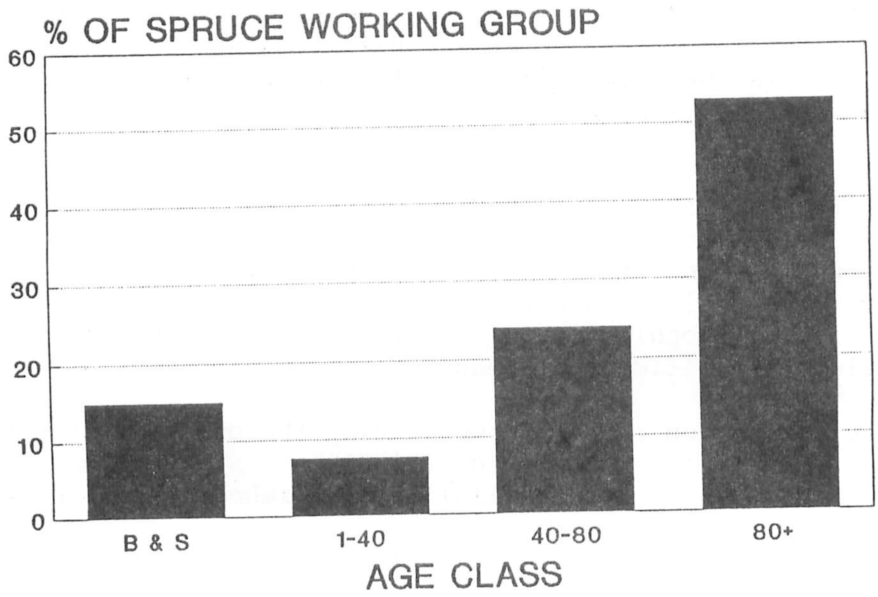

Figure 2. The relative proportion, by area, of the spruce working group in Ontario represented in each of four age classes. Rotation age for spruce is 75 to 100 years. B & S represents barren and scattered.

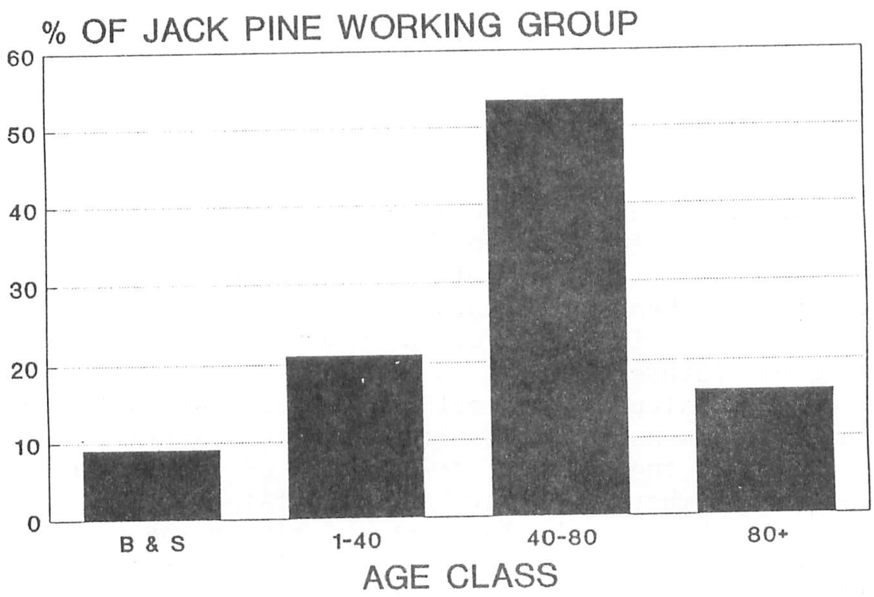

Figure 3. The relative proportion, by area, of the jack pine working group in Ontario represented in each of four age classes. Rotation age for jack pine is 45 to 70 years. B & S represents barren and scattered.

If we strive for and achieve normalization we will have:

1) a fully accessed forest resource developed around a strong skeleton of maintained roads

2) a pattern of stands of various age classes and species composition, all represented on a scale compatible with the range utilization of the featured species.

The desired level of diversity varies with the species being managed and this has a notable affect on the desired cut-block size (Fig. 4). This means that in the new forest all habitat-related life requirements should be met within 200-500 ha in deer range and within 500-3,000 ha, with stand sizes of approximately 100 ha, in moose range. In these blocks, the more diverse the stand ages, the better. Planning areas of 5,000 to 15,000 ha are desirable in caribou range with substantially less diversity. The different scale factors reflect the need to meet year-round habitat requirements for the featured wildlife species being managed and to distribute the positive influences of timber management activities to meet the needs of populations rather than individuals. The issue of normalizing the cut is partly resolved by addressing the other issues of minimum block size, timing of the return cut and access in the Timber Management Plan.

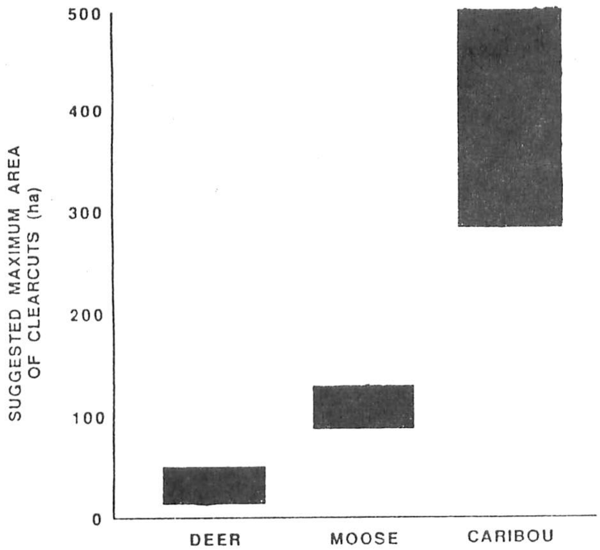

Figure 4. The recommended size of clearcuts is much smaller for deer than for moose and much smaller for moose than for caribou. Moose require more browse and shelter than caribou and therefore prefer a habitat pattern more like that of deer than that of caribou.

Cut Size

When guidelines are applied to timber management, they are often interpreted as a means of "breaking up the cut". The response to the guidelines is often, therefore, to leave as small a block of residual timber as possible and still meet the guidelines. This often results in unstable, small, irregularly shaped stands, which are highly susceptible to blowdown and a hindrance to site preparation, and to which it is not economically feasible to return at a later date. In addition, they are of little use in providing a more balanced distribution of age classes or stand structure. These small, low-quality blocks of standing trees may also be of as little value for wildlife as they are for timber.

Larger blocks of timber, which make a return cut economically feasible, also reduce blowdown losses and can contribute to better habitat for a large number of species such as marten or fisher.[2] The guidelines intend to support these furbearers through featured-species management.

Edge, the ecotone between two stand conditions, is a valuable habitat for many wildlife species. Irregularly shaped cuts increase the amount of edge between uncut and cut stands. Habitat value can be improved if one plans the size of a cut to suit the featured species and the shape of a cut to maximize edge.

Timing

The time that lapses between the harvest of one stand and that of adjacent stands or leave blocks can be considered in the context of a minimum age and a preferred age.

The minimum age, as stipulated in the guidelines, is set to ensure that adequate cover is provided from the regenerating stands before the second or return cut is begun. Lateral shelter can be provided when regenerating conifer vegetation has reached a height of 2 m (5 to 7 years), whereas overhead cover can be provided when regenerating vegetation has reached a height of 6 m or has attained canopy closure (Anon. 1988). The requirement for lateral or overhead cover will depend on the relative availability and proximity of summer and winter habitat and on the location of traditional winter concentration areas.

The preferred time until the return cut depends on whether harvest operations are occurring in an area with trees of various age classes. The preferred time could be expanded to as much as half of the rotation age in a forest with a poor distribution of age classes and relatively uniform stand composition.

In addition, a broad distribution of age classes and stand types in a planning area will benefit a large number of furbearers (Thompson 1988) and nongame species (Welsh 1988).

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2. Racey, G.D. and Hesse, B. Marten and fisher response to cutovers: a summary of the literature and recommendations for management. Ont. Min. Nat. Resour., Northwestern Ont. For. Tech. Devel. Unit, Thunder Bay, Ont. (unpubl.)

Timing of the return cut ceases to be an issue when the distribution of stands ready for harvest coincides with the patterns necessary for the management of moose or deer because all the timber reaching merchantable age can then be harvested. This is conducive to better crop planning and, ultimately, better forest management.

Access

Access is important to both timber and wildlife managers for the same reason: it permits the best and most efficient use of the resource. Resource utilization is still limited by access and, to a certain degree, this factor has contributed to the existing pattern of age distribution and location of stands.

The sooner we are able to establish access to the resource on the basis of a permanent, all-weather road network, the easier it will be to work together towards normalization of the cut. In the short run, this would imply some sort of accelerated access program similar to the existing FMA roads program. An accelerated road construction program would:

1) hasten normalization

2) create opportunities for "melding" wood costs

3) increase harvest flexibility by season or fiber mix

4) increase opportunities for consumptive and nonconsumptive use of wildlife resources

5) create opportunities for other resource development based on mining and tourism.

Access is one of the major factors limiting normalization. However, development of an expanded access network must not only address the issues of timber availability, wildlife fisheries resources and cut normalization but also respect the rights and privileges of the existing remote tourism industry.

Priorization

Prime land, for the purpose of this paper, can be defined as land capable of high productivity for the resource being managed according to the priorities of the day. This means that prime land may change as our production methods or management objectives change to take into account new technologies or high priorities. It also implies that there may be prime land not only for jack pine or black spruce, sawlogs or pulp, but also for deer, moose or caribou.

As the timber industry inevitably moves toward prime land management an interesting range of options develops that either reduces or increases the potential conflict concerning the application of habitat guidelines during timber management.

The identification of prime land opens up the possibility of partitioning or dedicating the land base to specific management objectives: the production of timber or of wildlife on the basis of economic or social priorities. This may be suitable for relatively small parcels of land but is contrary to our strongly held belief in multiple use on the bulk of the land base.

However, evidence would suggest that land with a high capacity for timber production also has a high capacity for wildlife production, particularly moose or deer. Therein lies the dilemma. Increased investment in timber on productive sites and the greater effort dedicated to protecting that investment through planning, site preparation, planting and tending may mean that a new approach (other than range management with a featured species such as moose or deer) may be required.

Four levels of intensity in forest management can be identified: extensive, basic, intensive and elitist (Anon. 1986b). Almost all silviculture in the boreal forest of Ontario is either extensive or basic. The wildlife equivalent of basic silviculture is range management and the moose and deer habitat guidelines are compatible with this intensity of management. However, at present, there are no well documented wildlife management strategies that are the counterparts of intensive or elitist silviculture in Ontario.

The fundamental issue on highly productive sites will remain as follows: the greater the investment and the greater the demand for products, the more intensive the competition for the resource will become. In essence, prime land management may increase conflict over land use in some areas and virtually eliminate it in others.

SOLUTIONS

Normalizing the Cut

Normalizing the cut by altering the age structure and distribution of stands in the boreal forest is a task of monumental proportions, and road access is the cornerstone upon which the strategy must be built. However, even if the access issue is addressed and resolved through creative funding and cooperation, some very difficult and, to most of us, unsavory options have to be considered. How do we change, through time, the imbalance that has developed over the last 75-100 years?

The first option is to encourage rejuvenation of stands in the large expanses of old-growth forest to ensure a greater diversity of stand ages prior to the achievement of road access. This could be accomplished by a modified fire suppression policy that identifies areas in which rejuvenation is beneficial. Management in the old-growth forest is difficult because of lack of access but that is also the reason, apart from distance to the mill, that it is largely old growth.

The second option is to begin early harvest in stands that are now 40 to 50 years of age near the middle of their anticipated rotation and close to the mill. This would ensure that by the time the stands reached their biological rotation age, there would be an abundance of vigorous young stands to provide habitat for wildlife. This could have the added benefit of putting some of the more productive land back into production by using far better management practices than were used 40 years ago.

The final option is to leave accessible, merchantable timber in reserves or uncut blocks for periods ranging from 5 to 7 years, or the minimum time required for lateral shelter to develop, or up to half the age of rotation when the objective is to help diversify the age structure and distribution of stands.

All of these alternatives cost money and will result in the loss of wood fiber or reduced efficiency in its use until the goal of normalization has been reached. It is neither wise nor advisable to rely heavily on any one of these options. However, if all of them are used in moderation where conditions warrant, we can make small but significant gains towards a normalized age and stand structure.

Differential Investment

Many of the problems or conflicts seem to arise in the application of the moose or deer habitat guidelines when the question of economics is raised. We do not intend to address the issue of the economics of wildlife because it is far beyond the scope of this paper. However, we must recognize the impact of investment intensity on the interpretation and application of the guidelines.

Extensive management for jack pine and range management for moose are quite compatible. Higher levels of investment associated with crop planning for optimum yields on designated stands will help to focus the application of the guidelines so as to recognize this level of investment. Finally, range management objectives can be enhanced if the timber industry recognizes and increases its involvement in mixedwood management. This will not only enhance wildlife habitat in the early stages of development through the production of browse and summer shelter but also produce valuable early winter habitat, preferably in close proximity to intensively managed conifer stands.

Both timber and wildlife managers benefit from increased investment because it can help them achieve their respective objectives, increase their confidence in the product being developed and help them to focus on priorities.

Preharvest Prescriptions

Preharvest prescriptions based on field inspections of the site are essential to the efficient application of the habitat guidelines. First-hand, verified information on vegetation, soils and wildlife values is necessary for crop planning and the removal of arbitrary decisions in the planning process. Stand allocation, reserve layout and silvicultural treatment can be formulated to produce good wildlife habitat and a higher return on investment from timber management.

Effectiveness Monitoring

The guidelines for the provision of moose or deer habitat in timber management are based on the best information currently available. The guidelines can be developed over time to take into account changing priorities or levels of investment or new information. Effectiveness monitoring is essential not only to ensure that the guidelines accomplish what they were intended to accomplish but also to permit identification of new information as well as improvements in the guidelines and the way in which they are applied in timber management. No program can function effectively without some feedback on management actions. Wildlife management is no exception. Effectiveness monitoring combined with adaptive management can improve the way we do business. We must verify whether or not both wildlife and timber targets are being met if we are to be confident in our management. We must also determine more precisely why targets were or were not met so that we can propose constructive management alternatives.

In addition to management of the featured species, monitoring is required to ensure that other game and non-game species habitat requirements are met through the application of the moose and deer habitat guidelines. The effectiveness of the strategy of featured-species management must be confirmed before we can determine if the controls now placed on timber management are inadequate, adequate or excessive.

Responsibility

The responsibility for forest management on crown land rests with OMNR, the timber industry and the public. OMNR is responsible for legislation and enforcement. The industry is directly involved in planning and the operational aspects of timber harvest. The public, ultimately, is involved in setting priorities for crown land use.

Management of forests in the best interests of the public is the standard that must be met. This standard sets the cost of doing business according to the stewardship of our natural resources that is expected by the public. The allocation of financial responsibility rests ultimately with the public, as taxpayers, company employees and consumers.

The investment balance between industry and government must be negotiated to reflect the proportion of private and public sector benefits. It is unfair to place an excessive financial burden on private investors to accommodate the needs of the general public. But an acceptable level of "corporate citizenship" is expected of the tenant of public land. To each there is a burden of responsibility.

CONCLUSIONS

Until normalization of the age structure and distribution of stands is achieved, there will be inconsistencies in the economic rationale behind the application of the moose or deer habitat guidelines as a featured-species management strategy. This means that we must not only resolve the issues of minimum block size, length of time until a return cut, the establishment of priorities for the land base, differential investment and accelerated access but also determine better ways of evaluating the economic and social impact of our management actions.

The only fact that is perfectly clear is that investment in forest management must increase in the short run before wildlife and timber management can realize the full benefits of a forest resource that has the temporal, spatial and ecological specifications users demand.

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WILDLIFE IN FOREST MANAGEMENT: FROM CONSTRAINT TO OBJECTIVE

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Abstract.--The tools and knowledge are now in place for modeling the dynamic response of many wildlife species to timber operations, and in spatial and temporal terms are equivalent to those of wood-supply analyses. This paper describes an initial attempt to simulate the potential response of a regional population of white-tailed deer in central New Brunswick to future habitat alterations resulting from a 25-year timber-management plan. Key features of the exercise include a habitat-responsive deer-population simulator connected to a spatially explicit representation of food-supply changes in the study area. It is concluded that forest-management decisions could be much better informed from the wildlife point of view with routine wildlife-impact analyses of the type described herein.

Résumé.--On possède aujourd'hui les outils et les connaissances nécessaires pour modéliser la réponse dynamique de nombreuses espèces fauniques aux opérations forestières. Ces outils sont équivalents, en termes spatial et temporel, à ceux qui servent aux analyses des approvisionnements en bois. Cet article décrit une première tentative de simulation de la réponse potentielle d'une population régionale de cerfs de Virginie dans le centre du Nouveau-Brunswick aux altérations de l'habitat qui résulteront d'un plan d'aménagement forestier de 25 ans. Parmi les principaux éléments de l'étude, mentionnons la mise au point d'un simulateur de la réponse à l'habitat de la population de cerfs relié à une représentation spatialement explicite des changements dans les approvisionnements alimentaires dans la région à l'étude. L'auteur conclut que les décisions en matière d'aménagement forestier pourraient être beaucoup mieux documentées sur la faune si elles se fondaient sur des analyses régulières d'impact sur la faune du genre décrit dans ce rapport.

INTRODUCTION

Recent efforts have led to greater awareness of the importance of wildlife in forest management (e.g., Bunnell 1985; Dauphiné 1985; Anon. 1987, 1988a,b; Thompson 1987; Bourchier 1988). Some (e.g., Thompson

1987), however, believe that little progress has been made in integrating wildlife considerations "properly" into forest-management decision-making.

My impression of how wildlife enters into forest-management decision-making in most of eastern Canada is as follows. For any forest-management unit, short-, mid- and long-term targets for timber yield are established, and short- and mid-term cutting plans are drawn up. Wildlife values, because of habitat considerations, constitute constraints on what the wood harvesters are allowed to do. These constraints exist in the form of habitat guidelines for particular species, e.g., moose (Allen et al. 1987, Anon. 1988c), and also in the form of review of individual forest-management plans by wildlife biologists.

Wildlife interests are at a distinct disadvantage nowadays with this approach to influencing forest management. If timber interests are using simulation tools to forecast timber availability and harvests, and wildlife interests are not (typically the case today), then the former can point out the disadvantages, in terms of expected timber-harvest costs, of applying wildlife-habitat considerations. The latter, however, cannot point out, in terms of expected wildlife benefits, how much greater the wildlife potential or carrying capacity would be if those habitat considerations were applied. The timber interests can justify their position, with measured indicators, on the basis of economic costs, but the wildlife interests must use persuasion or regulate their position into practice on the basis of unmeasured indicators.

Suppose that (a) measurable objectives for future wildlife populations could be set, (b) relationships between specific wildlife populations and their habitat could be quantified, (c) all stands in a forest could be described in habitat terms, and (d) wildlife interests had tools for exploring wildlife potential in a forest, in response to management intervention, similar to those used by the timber interests (e.g., Baskerville 1985). I believe that, while this is not sufficient, it is certainly necessary to help integrate wildlife considerations into forest-management decision-making. The benefits (summarized below) include mainly the ability to move from a position of constraint to one of objective, wherein wildlife potential stands alongside timber potential in so-called tradeoff analyses: what is the wildlife potential as a result of specific changes to a forest-management plan, and with what changes in wood-supply potential?

I deliberately did not say: "with what **costs** or **losses** in wood-supply potential?" So little of this kind of analysis has been done (if any) in forest-management planning that I suspect that clever manipulation of harvest and silviculture schedules on account of wildlife-habitat considerations may uncover intervention schemes that improve both wildlife and timber potential. At the very least, though, in such analyses we should be looking for ways of increasing wildlife potential substantially (if this is desirable), with little change in the cost of harvesting timber and carrying out silvicultural activities. Some such opportunities are sure to exist among the more than one hundred forest-management units in Ontario.

Arguments have often been advanced that the data and knowledge bases for building and using such models are so inadequate as to preclude meaningful results. I disagree. Wood-supply models use yield curves or tables to project stand performance into the future. It is precisely this kind of data that forest-management researchers so often identify as woefully inadequate. For other reasons, too, wood-supply modelers are faced with considerable uncertainty. Especially if wood-supply analyses are projected beyond a decade or so, the forecasts can and will be invalidated by a host of factors kept constant or unaccounted for in the analyses, e.g., fire, disease, pests, weather, even long-term climatic change. So, even though the wildlife interests have to contend with the very difficult problems of obtaining forest inventories in terms of habitat, and relating habitat to wildlife-population potential, both timber and wildlife interests are faced with considerable uncertainty in their long-term forecasting studies.

In the remainder of the paper, I briefly highlight some basic features of a simulation model that I built recently (Duinker 1986), partly to show that the environmental impact of economic development (such as forestry operations) can be forecasted meaningfully in quantitative terms with due regard to both temporal and spatial variability. I conclude with some lessons from that exercise, and close with a few thoughts on the potential for using such analyses routinely in improving wildlife considerations in forest-management decision-making.

POTENTIAL EFFECTS OF FOREST OPERATIONS ON DEER: A CASE STUDY IN NEW BRUNSWICK

My aim was to undertake a quantitative assessment, according to a protocol I had set out for defensible and useful environmental-impact forecasting, of the indirect effects of herbicide use, as proposed in an industrial forest-management plan for a central New Brunswick forest, on white-tailed deer (**Odocoileus virginianus** Zimmermann). Through discussion with several local officials, it was agreed that white-tailed deer was an appropriate species to examine because of its importance to hunters and non-hunters alike, and because of the general concern that herbicide use may influence deer through food supply. The deer response would be gauged mainly in terms of total number of deer in the study area over time.

The prevalent silvicultural use of herbicides in New Brunswick is for release of very young conifer plantations from competing non-conifer vegetation. The concern for deer arises from the notion that they rely on new openings in forested habitat to provide herbaceous forage in spring, summer and autumn, and some woody browse in winter. Biologists now realize the important contribution of non-winter food supply to the ability of deer to survive through winter. In adapting to harsh winters in the northern parts of their range, deer accumulate reserves of fat over summer and autumn that can be burned for energy in winter. Deer survival through winter is partly predicated on the amount of fat deposited, which is largely dependent on the quality of non-winter range. Hence, silvicultural activities that reduce the amount of herbaceous deer forage in new openings influence summer food supply and thus have the potential to reduce the ability of deer to survive through winter.

To assist the decision-makers, it was agreed that forecasts should be made for the deer population in response to timber harvest alone, timber harvest followed by regeneration by planting but no herbicide use, and finally, harvest followed by regeneration by planting and use of herbicides. This way, the effects of herbicide use could be put into a context of habitat changes caused by other forest operations that can occur alone but always precede the use of herbicides. In addition, it was considered important to place the impact of these forest operations on the deer population in the context of the impact of severe winter weather.

Although this study was concerned with only part of the total timber licence (some 44,000 ha), the area was large enough to account for the spatial dynamics of deer-forest interactions, and was considered an acceptable size for demonstration purposes. For impact forecasts, a 25-year time horizon, with annual resolution, was used since the management plan has a 25-year horizon, and deer populations respond to changes in habitat structure relatively rapidly.

The Forecasting Model

The simulation model comprises two fairly independent submodels -- a habitat submodel and a deer-population submodel (Fig. 1). The only interaction between the two components is the passage of food supplies and a hunter-access index from the habitat submodel to the population submodel. Hence, the model deer have no influence on the model habitat, a reasonable assumption in this case, since deer densities are rather low.

The food-supply projections from the habitat submodel are responsive to forest operations, including harvest, planting and herbicide use, and also to winter weather. Schedules for the forest operations were taken from the management plan, and reasonable alternatives to these schedules were formulated for impact-assessment purposes. For timber harvest, eight alternatives were prepared in which both harvest volume over time and the spatial patterns of harvest were varied. For regeneration, four alternatives were devised, with variations in the proportion of annual cutover planted, and in the proportions of black spruce (**Picea mariana** [Mill.] B.S.P.) and jack pine (**Pinus banksiana** Lamb.) planted. For herbicide use, I created 13 alternatives that combined variations in product applied (three products), the type of plantations to be treated (both species or spruce only), and year of

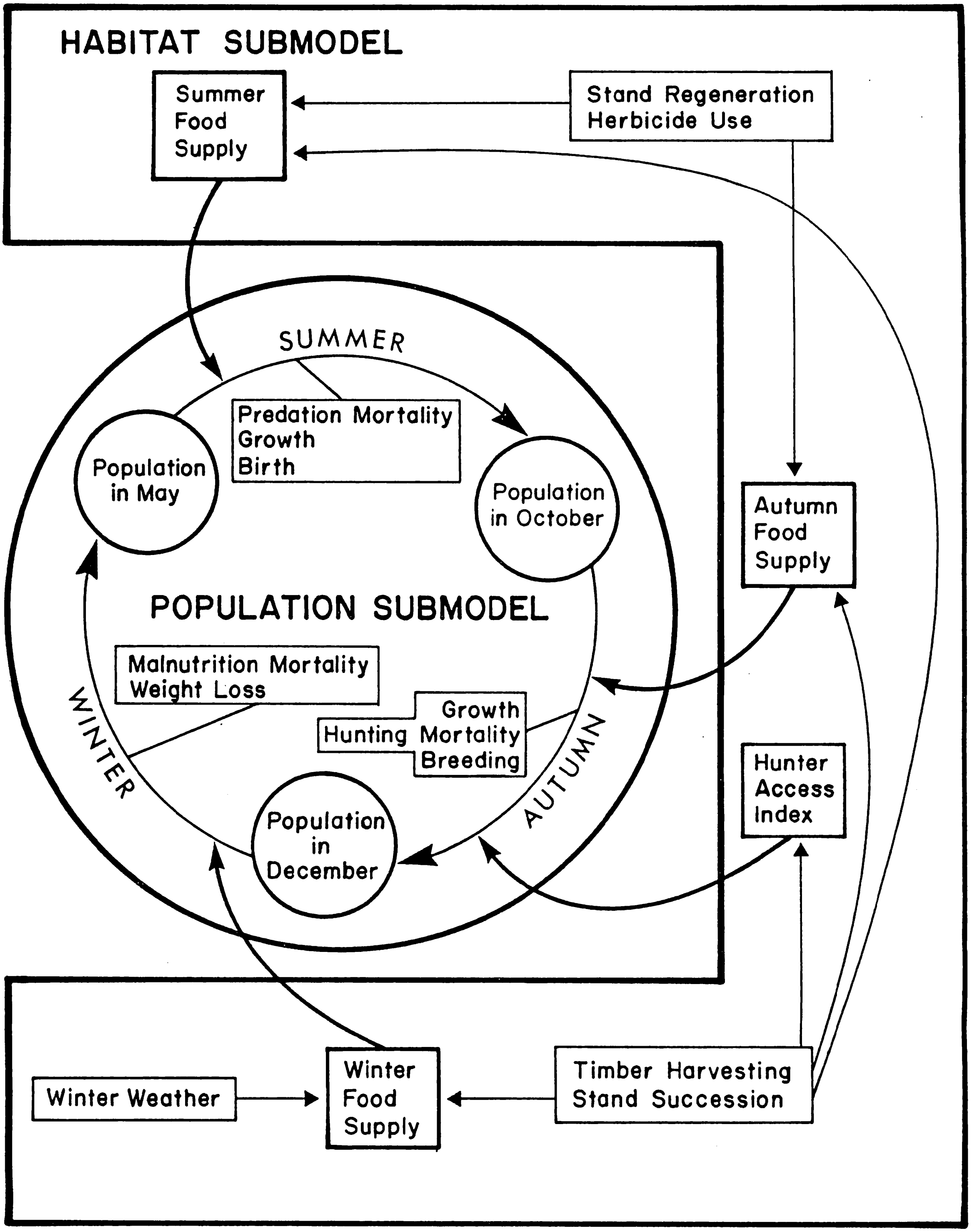

Figure 1. Conceptual model of the deer-habitat system

treatment after planting. A scheme was devised to permit winter food supplies to vary according to an annual winter severity index, future time streams for which were constructed according to a probability density function of annual winter severity over the past few decades. Thus, winter cover for the deer was mimicked through provision of winter food supplies calculated on the basis of cover stands only, but these food supplies were adjusted upward by the degree to which the winter severity index indicated light snow cover (and thus foraging of the deer beyond the cover stands).

The habitat in the study area was described in the New Brunswick Forest Development Survey (FDS) and was available in digital form for analysis by means of a geographic information system (GIS). To accommodate the problems of having (a) a stand-based (in the order of 10^0-10^2 ha) description of habitat features, (b) a wildlife species that has home ranges in the order of 10^2-10^3 ha, and (c) a study area of 44,000 ha, for which I sought the total impact and spatial patterns of the impact on deer, I devised a "roving window" technique. Briefly, the technique allowed a series of simulations (located on a regularly spaced grid across the study area; see Fig. 2) of the response of a small (about 50 animals) population of deer on a roughly circular piece of habitat of about 2,000 ha. After mathematically correcting for window overlap (see Fig. 2), I drew isopleths of deer response for specific time intervals through the grid to get a picture of spatial pattern of responses across the study area.

The deer-population submodel is a deterministic simulator that tries to capture the major biological events in the annual cycle of deer life in the New Brunswick woods (Fig. 1). Six population groups (two male, four female) are enumerated at three points during the year (late spring before fawning, autumn before hunting, and early winter after hunting). The model was structured especially to gauge potential deer responses to changing habitat (i.e., food and cover) conditions.

The first step in obtaining model projections of deer-population response to changing habitat conditions across the study area is choosing a set of timber harvest, regeneration, and herbicide-use options (one of each) from among the arrays prepared for the model. Then, the habitat submodel is processed to produce a 25-year set of forecast data for the food-supply variables and the hunter-access index for each of the 85 windows. The population submodel is also processed to produce 25-year forecasts of deer response to the specific habitat pattern in each window. Thus, the basic forecast data set corresponding to implementation of one set of forest operations in the model consists of 85 subsets (one for each window) of 25 values (one for each year) for the food-supply and deer-response variables. Such data sets were used to prepare the impact forecasts presented below and elsewhere (Duinker 1986).

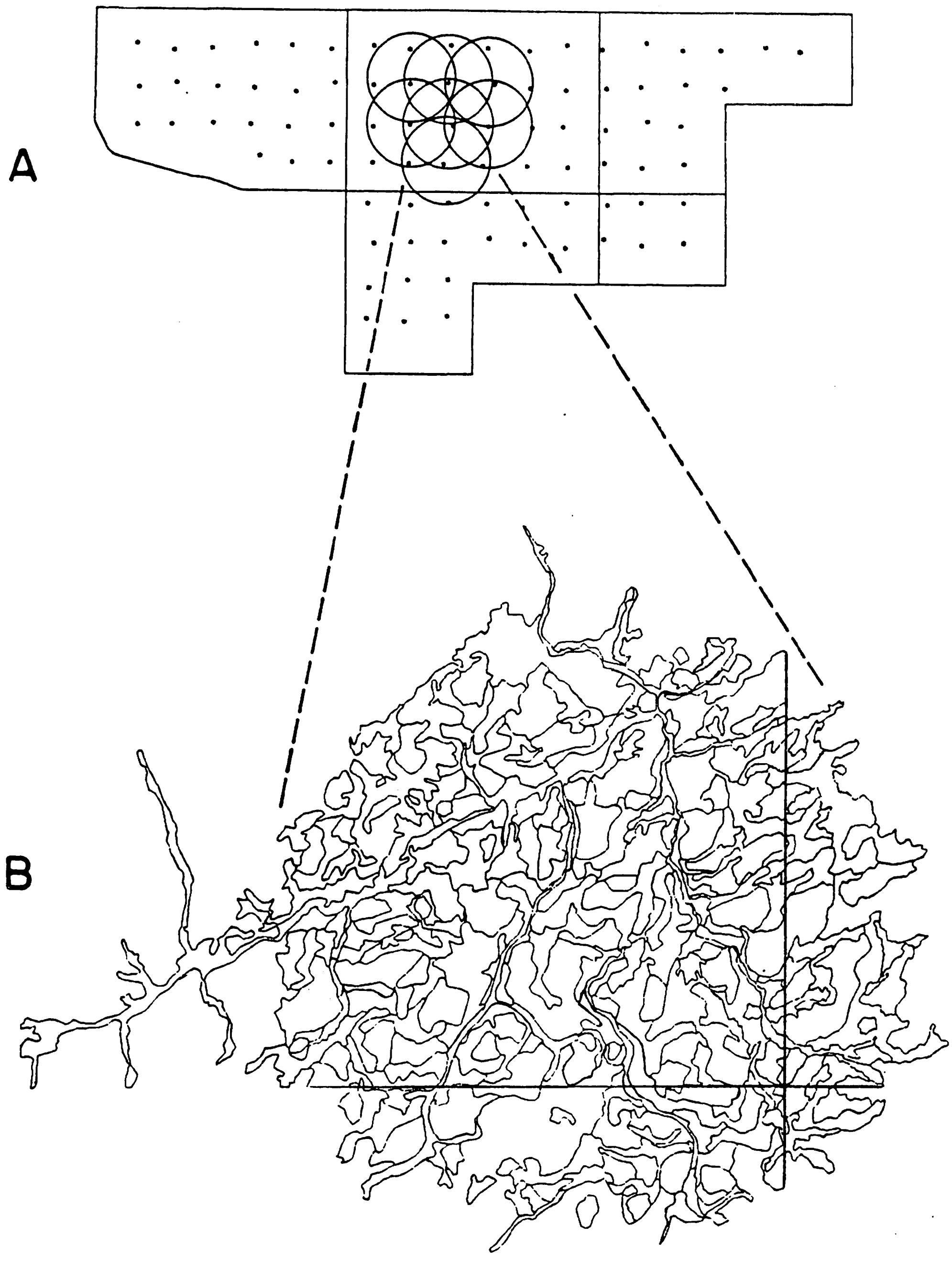

Figure 2. Disposition of habitat "windows" within the study area. A. Distribution of the 85 window centers across the area, with a small collection of approximate window boundaries to show overlap of window placements. B. Boundaries of stands in the New Brunswick Forest Development Survey for one of the windows (about 2,000 ha).

Impact Forecasts

Impact forecasts are produced by comparing results from specific simulation runs. For example, to project the response of total number of deer in the study area to different herbicide options, timber harvest and regeneration are held constant at one of their respective options, and the model is used to devise a set of projections for each herbicide option. The same procedure of holding two decision variables constant and altering the third is followed for exploring deer responses to timber harvest and regeneration options, as well as various options for winter weather severity.

For calculations of total impact, the effect of overlap of windows is corrected mathematically so that the 85 time-streams can be combined into one 25-year projection of total deer number for the entire study area. Consequently, these 25-year projections of total deer number, though produced with a forecasting model that accounts explicitly for spatial heterogeneity of the habitat, do not show spatial patterns of the deer across the study area. (This is done because of the difficulty of simultaneously displaying changes over time and space in report format. Such displays are indeed possible, and are indispensable in management and mitigation design.)

Sets of 25-year projections of total deer number over time can be plotted to permit visual inspection of the degree of impact (i.e., the differences between projections, as in Fig. 3). For many of the simulations, especially those exploring the effects of the herbicide and regeneration options, the projections were too similar to permit visual differentiation; therefore, the effects were also reported in numerical form. This involved addition of all 25 of the annual total population numbers in each projection to obtain one summary measure called "animal-years". Such a cumulative "occupancy" measure indicates the extent to which a habitat is expected to be occupied by deer over 25 years. The animal-years measure, though produced with a model that accounts explicitly for temporal variation of the deer population, does not show patterns of deer number over time. In this measure, both temporal and spatial heterogeneity are totally compressed.

My projections of animal-years and total deer population over time (see Duinker (1986) for details) suggest that the silvicultural use of herbicides according to the proposed management plan, and several plausible alternative herbicide options, do not affect deer numbers to a measurable degree. For this forest at this time, all herbicide options resulted in less than 1% change in deer animal-years, in comparison with no herbicide use. To set this finding in context, the model forecasts: (1) reductions in animal-years as large as 15-20% as a result of timber harvest, when compared with no harvest; and (2) reductions in the deer population as large as about 50% as a result of single harsh winters.

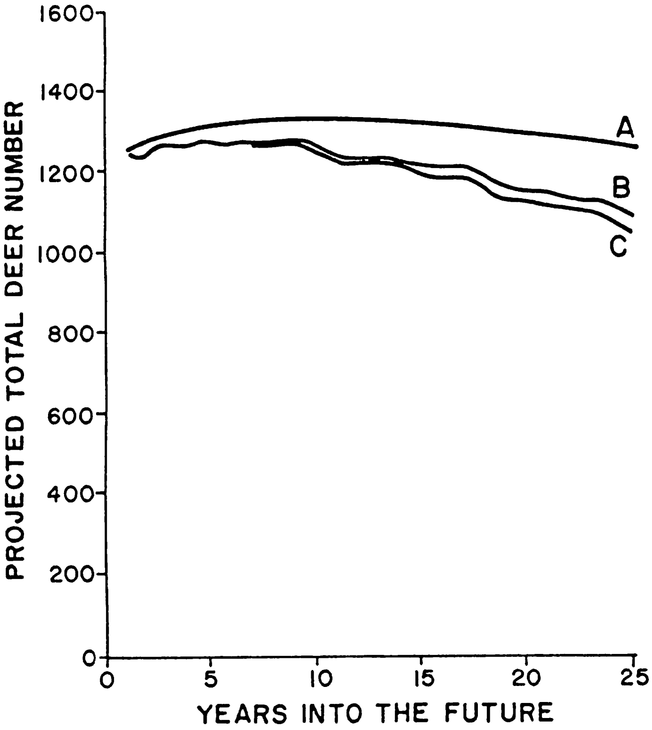

Figure 3. Projected total deer number on the study area in response to three sets of forest operations. For curve A, there is no timber harvest, regeneration or herbicide use. For curve B, the management-plan's harvest schedule is used, with a planting scheme of 20% of cutover area planted to black spruce and 20% to jack pine, and no herbicide use. For curve C, the timber harvest and regeneration activities of curve B are used, and glyphosate is used once shortly after planting on both spruce and pine plantations.

The trends indicated by the model will not necessarily continue beyond the end of the 25-year simulation period. What happens to deer numbers in the study area beyond 25 years depends entirely on the evolving summer-autumn and winter food supplies produced in the habitat. It is possible that the shortage of deer wintering areas (DWAs) that is forecasted for the last decade of the simulation period for most of the timber-harvest options could be offset just beyond the 25-year horizon by an abundance of young spruce (**Picea** spp.)-fir (**Abies** spp.) stands just entering DWA availability. This possibility was not explored in this study. However, if this were to be the case, the use of herbicides to release black spruce plantations from competition might hasten the improvements in DWA supply.

The model can also be used to investigate location-specific causes for habitat change leading to declines in the deer population over time. To do this, the data sets can be compressed into five sets of maps, one set for each 5-year period of simulation, showing distributions of stands scheduled for harvest, projected winter and summer-autumn food supplies, and projected deer numbers. With such an array of maps, one can determine where the greatest improvement in deer response should be attainable through redesign of harvest timing and location. Unfortunately, because of the need for a series of maps, an example of how such investigations might proceed cannot be given here (see Duinker 1986). Suffice it to say that, to ensure that mitigation design can be implemented, one would also need, at minimum, a spatial and temporal characterization of the stands that will be eligible for harvest, and the stands that will fulfill the criteria of potential DWAs. The simulation model is capable of satisfying both these needs.

LESSONS FROM THE CASE STUDY, AND OTHER PRINCIPLES

1. Forecasting environmental impact: better quantitative and wrong than qualitative and untestable.

I used this expression as the title for a paper (Duinker 1987) in which I argued that quantitative forecasts help to get environmental matters a proper seat at the decision table, and help us to learn as reality unfolds at odds with expectations. Qualitative forecasts (e.g., "changing the forest-management plan in this particular way will improve habitat, and that's good for deer") cannot help much either way.

2. Habitat-responsive, dynamic population models for animal species are now readily built.

I argue that analyses that project mid- to long-term wildlife potentials in response to habitat change as a result of forest operations must be able to show **dynamic** response of wildlife to habitat change if they are to be credible. Dynamic simulators for wildlife populations have been under development and in use for many years, but the majority have held habitat constant in favor of exploring questions related to, for example, hunting strategies or changing predation. Although this is a bold step in many ways, it is possible now to add dynamic habitat relationships to such models in a defensible way to explore population response to changing habitat.

3. GIS technology is indispensable to wildlife-habitat analyses.

Space and location really matter when it comes to responses of regional wildlife populations to spatially heterogeneous patterns of forest operations. Such analyses must contend with relations among stands, forests, animal home ranges, animal migrations, timber-harvest patterns, etc. Some key relationships between habitat and wildlife are such that the response of wildlife to habitat change in a particular location is often strongly predicated on habitat change surrounding that location. The only technology that enables modeling of such relationships is that of GISs. Now that GISs are becoming standard tools for wood-supply analyses, they are more and more available for habitat-supply analyses.

4. We do not manage wildlife, especially hunted wildlife, solely through habitat alteration; this is properly called management of habitat carrying capacity.

What I have described is a system that gives clues to the provision of a range of levels of habitat carrying capacity for deer. Habitat is only one of several important factors controlling wildlife populations;

hunting, natural predation, and disease, for example, can also be major factors that need to be taken into account by wildlife managers. Nevertheless, habitat is often limiting (in the sense that if the habitat were "better", more animals would probably live there), and for such cases I have described an approach that permits wildlife managers to interact with forest managers in pursuing wildlife goals through habitat modification. Let us consider the case in which a forest is to be managed specifically to meet wildlife objectives, with timber harvests as a secondary consideration. The simulation approach I described could be used to determine, for deer (or any other species for which such a system is built), what the habitat carrying capacity of a forest is now, and then what temporal and spatial patterns of forest operations such as timber harvest would be necessary to bring the carrying capacity to any desired level. My model indicates that there is not just one optimal mix of habitat (in terms of relative summer and winter food supplies) for deer in New Brunswick (and likely elsewhere), but rather that the two food supplies can be traded one for the other, within limits, with similar effects on the carrying capacities for deer. Outside these limits, raising the carrying capacity through provision of additional seasonal (i.e., winter or non-winter) food supply is not possible because the food supply of the other season is then itself limiting.

CONCLUSIONS FOR FOREST-MANAGEMENT DECISION-MAKING

I believe that investment in bringing wildlife concerns to the decision table in a form technically comparable to that of wood-supply concerns will be small in comparison with the concomitant enlightenment that will be provided with respect to the provision of better habitat for wildlife. Indeed, I believe we will find many instances in which such investments in knowledge will reveal possibilities for increasing wood supply while maintaining or improving habitat conditions. Until we try some analyses of the general kind I have sketched above, we will not know whether these possibilities exist.

We could also look at the simulation approach as another means of testing the effectiveness of the habitat guidelines now in place to direct the design of timber harvest with wildlife in mind. The traditional means of testing is, of course, field monitoring of areas treated according to the guidelines. Simulation is a cheap and effective means of checking our conventional wisdom (or sometimes conventional folly) about wildlife-habitat relationships at temporal and spatial scales and with temporal and spatial variability that are crucial but very difficult to handle with the mind alone. We need more than back-of-the-envelope calculations!

The forest-management decision environment, i.e., the deliberations between timber interests and wildlife interests in development of forest-management plans, will be perceptibly improved when wildlife-habitat considerations are no longer viewed as constraints on timber goals, and cooperative, simultaneous exploration of timber and wildlife goals can be undertaken. To achieve this, we need to structure our current knowledge of wildlife-habitat relationships into quantitative models that can generate plausible, dynamic, spatially explicit projections of potential wildlife response to habitat change. Granted, the knowledge is scant, but so is that of the wood-supply modelers. However, they have learned not to be held back; indeed, they have learned that such modeling helps clarify, as no other approach can, the field research that is needed to address their most serious uncertainties. Let us wildlifers catch up!

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ECONOMIC CONSIDERATIONS IN WILDLIFE AND FISHERIES: MULTIPLE-USE MANAGEMENT

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Abstract.--Several natural resource agencies currently incorporate economic criteria for wildlife and fisheries into multiple-use management and decision making. The United States Forest Service, for example, uses evaluation criteria in both national and forest-level planning. Controversy surrounds the choice and use of evaluation methods but progress is being made in establishing standard approaches.

Résumé.--Plusieurs organismes de gestion de ressources naturelles utilisent des critères économiques relativement à la faune et aux ressources halieutiques pour la planification d'aménagements polyvalents et la prise de décisions. Aux États-Unis, par exemple, le Forest Service emploie des critères d'évaluation dans sa planification tant au niveau national qu'au niveau des forêts. Le choix et l'utilisation des méthodes d'évaluation sont sources de controverses, mais des progrès s'accomplissent sur le plan de la normalisation des approches.

INTRODUCTION

When we consider management of a single resource, such as timber, it is natural to think in terms of future increases in wood volume as the primary output that will result from our investments. However, when we consider multiple-use resource management, we need to be aware that our investments can produce multiple effects, including both commodity and recreational outputs. For example, an investment designed primarily to increase wood volume can affect wildlife habitat and thus have an effect on future hunting opportunities.

In multiple-use management, when our forestry investments affect hunting, fishing, or other uses of wildlife, there is an economic effect that can be stated in terms of benefits and costs and should be accounted for in an economic analysis. However, establishing a unit of measure for these economic effects and then placing dollar values on them is substantially more difficult than is the case with timber outputs, in which prices can be observed directly in markets. The difficulties arise from the fact that the recreational activities associated with wildlife and fisheries generally do not have functioning markets in which prices can be observed directly, as are found with commodities such as timber. However, lack of established markets has led to the development of indirect methods to infer dollar values for recreational activities. This, in turn, has led to controversy concerning the application of indirect valuation methods and whether or not their results are commensurate with market prices for commodities.

My tasks in this paper are to (1) show how wildlife and fisheries fit into a multiple-use economics framework, (2) discuss the use of economics for wildlife and fisheries resource evaluation by the USDA Forest Service, (3) outline briefly some of the economic evaluation methods used by the Forest Service, and (4) discuss some of the controversial aspects of these methods. I will pay special attention to two key economic considerations, namely the selection of the economic unit of measure and the derivation of dollar values by which this unit of measure can be evaluated.

The Multiple-use Framework

In a multiple-use management context we may want to invest in wildlife and fisheries in order to 1) enhance directly wildlife and fish benefits, 2) mitigate adverse effects resulting from other multiple-use activities such as timber harvesting, or 3) protect the resource by preventing adverse effects. Theoretically, investment analysis of wildlife and fisheries projects is similar to procedures used for timber investments. Inputs and their costs are accounted for, a production function is developed to link inputs to outputs, and outputs are valued in dollars. If future costs and benefits are anticipated from the investment, interest rates must be selected for discounting. The results are usually presented in the form of an economic criterion such as a benefit:cost ratio, present net value, or rate of return.

The major differences between evaluating investments in recreational wildlife and fisheries on the one hand and timber investments on the other are in the data available for linking inputs to outputs and in determining dollar values for outputs. Production data for wildlife and fisheries are in a relatively primitive state of development in comparison with data for timber, and there is no established market in which one can observe dollar values. A sportsman does not buy an animal or fish outright. The typical procedure is for hunters to obtain licences from the state granting them the right to harvest an animal. A licence fee represents part of the value of the hunting experience, but typically is only one of several expenditures made by a hunter. Occasionally there may be an access fee to enter a particular tract of land, but fees are not as yet widely enough established or standardized to use as a basis for prices except perhaps in a few localities.

In spite of the lack of functioning markets for recreational wildlife and fish uses, a body of knowledge and methodology for evaluating these uses has emerged over the past 30 years. This emergence has resulted from the need to compare multiple-use outputs in common terms, i.e., dollars. The need has been influenced by greater competition between resource areas and among resource agencies for budget dollars appropriated by Congress, the emphasis placed by the executive branch and Congress on better financial accounting for benefits and costs, and legislative mandates requiring closer attention to the economics of resource management. As a result of these influences, economic evaluation of wildlife and fisheries activities and the estimation of dollar values for the recreational aspects of wildlife and fisheries have become widespread in both federal and state resource agencies in the United States. Those who use economic methods in wildlife and fisheries include the principal forest and range land management agencies--the USDA Forest Service and the Bureau of Land Management--and many state fish and game agencies. Two prominent examples of states in which agencies use these methods are Idaho and Montana, both of which have recently sponsored studies that produced values for recreational use of wildlife and fisheries resources.

Use of Wildlife and Fisheries Economics by the USDA Forest Service

Economic analysis has been adopted and standardized by the USDA Forest Service. Specific legislation (the National Forest Management Act of 1976) establishes mandates for the consideration of economics in programs, plans, and projects by the Washington office, by the regional offices, and particularly by the National Forests. The legislation has been codified as regulations and these in turn have been translated into specific manuals and handbooks to guide and direct the use of economic analysis. The directives specify that both economic efficiency and economic impacts will be addressed. Efficiency analysis includes the consideration of costs and benefits of projects while impact analysis deals with the effects of these recreational activities on communities (e.g., changes in employment levels).

Wildlife and fisheries resources are covered by these economic directives. At the national level, economic analysis of multiple-use resources is integral to the 5-year program planning cycle required by the Forest and Rangeland Renewable Resource Planning Act (RPA) of 1974. The development of dollar values for resource outputs, including recreational wildlife and fish, is part of the planning effort. One of the results of the RPA planning effort is a program document (a strategic plan) produced every 5 years. The 1985 RPA program document (Anon. 1986) displayed dollar values for resource outputs, including those of wildlife and fisheries (Table 1). At the National Forest level, multiple-use economics is also an integral part of the forest planning process.

Despite the Forest Service's acceptance of and standardization in the use of economics for wildlife and fisheries planning and investments, including the values shown in Table 1, controversy has surrounded this activity. Specifically, objections and concerns have been raised about the magnitude of the dollar values shown in Table 1 and their use in National Forest planning, the possibility that these values may not be comparable with commodity values, and the unit of measure employed to account for use, i.e., the 12-hour user-day.

Table 1. National Forest System wildlife and fisheries values for the initial year of the 1985 RPA program, by USDA Forest Service region (1982 dollars)

Region	Big game use ($/WFUD)	Non-game use ($/WFUD)	Other game use ($/WFUD)	Resident fish use ($/WFUD)	Anadromous fish use ($/WFUD)
1	28.52	23.00	19.32	10.12	21.16
2	37.72	23.00	17.48	10.12	NA
3	27.60	23.00	16.56	11.96	NA
4	28.52	23.00	17.48	10.12	21.16
5	27.60	23.00	16.56	11.04	28.52
6	27.60	23.00	17.48	13.80	30.36
8	23.00	23.00	16.56	11.96	NA
9	35.70	23.00	19.32	11.96	34.96
10	27.60	23.00	17.48	10.12	30.36

[a]WFUD = Wildlife and Fish User-Days, equivalent to 12 person-hours of use

In the 1985 RPA program, dollar values for wildlife and fisheries user-days are based on simulated market prices, i.e., an attempt was made to estimate what prices would be if a market actually existed. This was done so that commodity and recreational prices could be compared on an equitable basis, i.e., a market-price basis. There was criticism of this approach, and especially of the results, which produced prices significantly lower than results from numerous other studies that were based on willingness-to-pay methodology. Suggestions were made that the Forest Service abandon the simulated market approach and adopt willingness-to-pay methods (see section on Current Developments). The use of the user-day as a unit of measure was also criticized. The Forest Service uses a 12-hour visitor- or user-day as its standard measure of recreation. This measure, which is based on aggregated use by one or more people, is criticized as giving a distorted view of recreational use. A proposed alternative is the **activity day**, which is based on the average number of hours in a day actually spent in an activity. An activity day is usually some fraction of a 12-hour user (visitor)-day.

Economic Considerations and the Process of Evaluating Wildlife and Fisheries

The Forest Service is specifically charged with management of wildlife and fish habitat. It is not responsible for the management or harvest of fish or game populations, a task usually reserved for individual states. The Forest Service tasks of managing include protecting and improving the habitat. Protection involves taking measures to prevent or reduce the risk of adverse effects of timber harvest. For example, one might leave a buffer strip of trees alongside a stream to protect fish habitat and maintain a fish population. Improving the habitat involves changing the character of vegetation, usually for the purpose of increasing a wildlife population. For example, one might remove trees to promote the growth of wildlife forage or conduct prescribed burns to change species composition.

Management of habitat is designed to maintain or increase wildlife or fish populations. However, economists do not attempt to place a value directly on changes in wildlife or fish populations. They focus instead on changes in human use resulting from these population changes. Human use takes the form of hunting, fishing, or nonconsumptive use (bird-watching, photography, nature study). Focusing on human recreational use is preferable to trying to place a value on animals, but measuring recreational use is not simple.

There are various approaches to measuring use. One can measure a **trip** or **outing** varying in duration from a few hours to several days, depending on the activity and location; one can use an **activity day** based on some average number of hours spent in an activity during a day but varying in duration by type of activity; or one can adopt an approach that aggregates use into a standard duration for every activity, such as a visitor- or user-day of 12 hours. Each approach has its advantages and drawbacks, but a major problem is the considerable variation in the use of these measures by different resource agencies and from study to study.

After a unit of measure has been selected, the problem is to select a dollar value. If outputs are bought and sold in a market, generally a price is available, but established markets or prices are not generally available for wildlife and fish recreational use on public lands. On many private lands, particularly in the eastern half of the United States, the practice of charging access fees for the right to hunt or fish on private land is growing. A market is emerging and with it a potential data base for hunting and fishing prices. However, there are still serious problems with this emerging data base. These problems include considerable variation in the services provided by landowners that are covered by an access fee, including guide services, lodging, and meals. There is also the technical question of the validity of applying such results to public lands. In the absence of established functioning markets and evidence of reliable transactions, economists have developed methods to measure indirectly the economic benefits of wildlife and fisheries activities.

Valuation by Indirect Methods

Early attempts to value wildlife and fisheries use were based on expenditures, i.e., what a sportsman actually paid out in cash for the hunting or fishing experience. Economists pointed out that, although expenditures information was important, to obtain the total value of an experience we must measure what sportsmen were willing to pay beyond their expenditures. In the early 1960s two basic approaches emerged, the travel-cost method (Knetsch 1963) and the contingent-valuation method (Davis 1964). By 1978 these methods had been developed to the degree that they were adopted by the United States Water Resource Council (Anon.

1979) for evaluation of recreation benefits in federal water resource projects. In the last 10 years considerable work has been done to refine these methods and there is a growing body of literature detailing this work (Sorg et al. 1984, Decker et al. 1987). I shall briefly contrast the concepts of a "willingness-to-pay" price and a "market" price and discuss the major methods used, i.e., the travel-cost and contingent-valuation methods.

Willingness-to-pay in comparison with market price: In an established market for a specific commodity, e.g., salmon sold in a fish market, there is a specified price that a consumer must pay to obtain the salmon. This price has been established by the interactions of large numbers of buyers and sellers, in other words, by demand and supply. If the price of the salmon should rise, many buyers will decide the fish is no longer worth the price, but many others will pay the higher price. If this process of increasing the price is continued more buyers will drop out, but others, though fewer in number, will be prepared to pay a higher price. What we observe is that when a consumer buys a commodity, very often the market price he pays is some fraction of what he would be willing to pay if he had to bid for it. The difference between what he actually pays and what he would be willing to pay represents a surplus of value to the consumer. Economists use the term "consumer surplus" for this effect.

Travel-cost method: Travel-cost methodology has been developed over three decades and its foundations are well established. The travel-cost method is based on the premise that, although one cannot measure directly the value a consumer receives through recreational experiences, one can measure the costs the consumer incurs in traveling to and from the site. The method uses travel cost as the primary cost variable in the consumption of many recreation experiences. The analyst traces out the demand function for the activity at a particular site by assuming that the travelers would react to an admission price in the same way as they would to an increase in travel costs, all other expenses being assumed equal. The travel cost varies on the basis of the location of the site and the user's place of residence. It is this variation in travel cost that allows the demand function for travel to be observed and "willingness-to-pay" to be determined.

Contingent-valuation method: In comparison with the travel-cost method, which relies on expenditure and visitation behavior to reflect the implicit value of recreational experiences, the contingent-valuation method relies on surveys to elicit price estimates directly from consumers under simulated market situations. This method can be especially useful in the valuation of individual components of multipurpose recreational outings such as those in which camping, hiking, and fishing may all be involved. This method can also be useful when the level of use is subject to a capacity constraint such as rationed hunting licences for certain game species.

The contingent-valuation method asks individuals what they would be willing to pay to engage in an activity. Willingness-to-pay estimates may be obtained on an "initial bid" basis, wherein an individual is asked to provide a price estimate for the recreational experience, or on an "iterative bid basis," wherein he is successively asked if he would pay more until a negative response is obtained. Several types of bias may arise in obtaining responses from interviewees. Hence, special care must be taken in designing contingent-valuation studies.

Current Developments in Wildlife and Fisheries Recreational Economics

Currently, the economic information needs of the wildlife and fisheries resource sector are great. Information concerning production functions is not well developed. Work is under way to model wildlife and fisheries habitats, but more of this research is needed to give us accurate and reliable data on the wildlife and fish outputs that will be produced as a result of our investments.

Considerable work has been done in developing willingness-to-pay values for recreational outputs. However, more information is needed on market transactions. With the growing practice of charging access fees for opportunities to hunt, fish, and view wildlife on private lands, a useful data base for future pricing studies may emerge.

A major economic evaluation issue within the Forest Service has been the commensurability of output prices for the various multiple-use outputs, particularly commodity vs recreational outputs. On the one hand, recreational economic values are typically based on willingness to pay, and hence represent a broader perspective of social values. On the other hand, commodity values are based on market prices, which represent the perspective of the business firm. It has been argued that they are not being valued on a commensurate basis, that comparing recreational values with commodity values is inappropriate inasmuch as they are based on different measures or standards. Until recently, the solution was to achieve commensurability by assigning simulated market prices for wildlife and fish recreational activities. However, the methods used were heavily criticized.

A recent development within the Forest Service is designed to resolve this issue. Recently, the Forest Service has adopted three different perspectives, called "accounting stances", to be used for efficiency analysis and resource output pricing. The three accounting stances to be used in the 1990 RPA program are: (1) existing fees, (2) market clearing prices, and (3) willingness to pay. Existing fees provide the narrowest focus, accounting for actual monetary expenditures and receipts. For many recreational activities, receipts are zero. Market clearing prices mirror private industry approaches to evaluating investment proposals, i.e., through attention to market prices. The willingness-to-pay approach is the broadest in focus, as it takes into account monetary values that are not reflected in market prices.

CONCLUSIONS

This paper has provided a brief overview of some of the economic considerations appropriate to wildlife and fish in a multiple-use context. I have covered development of production functions, measurement of use, economic evaluation of benefits and comparison of multiple-use resource values. It is important to note that the use of economics to evaluate wildlife and fisheries resources in a multiple-use context is a relatively new and developing field. Most of the economic evaluation in this field has been done in the last 10 years. There are many challenges and research opportunities for those interested in this type of work. Finally, the exchange of ideas and information is essential if there is to be progress in multiple-use evaluation. It is important that we continue to provide opportunities for discussion, such as this symposium.

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SESSION V: Tackling the Unknowns

THE FOREST DATABASE

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Abstract.--The forest database comprises several datasets. A tabulated list of datasets briefly describes their content, form, software and source. Datasets include planimetry, forest thematic cover, forest history, stratification of use, and forest environment. For specific investment analyses the manager must select the appropriate dataset.

Résumé.--La banque de données sur les forêts est constituée de plusieurs ensembles de données. Une liste de ces ensembles présentée sous forme de tableaux, en décrit brièvement le contenu, la forme, le logiciel et la source. Y figurent, entre autres, des ensembles de données sur la planimétrie, les cartes forestières thématiques, l'histoire des forêts, l'allocation des utilisations et l'environnement forestier. Pour une analyse précise des investissements, la gestionnaire doit choisir l'ensemble approprié.

INTRODUCTION

The topic of this session is "Tackling the Unknowns", and I am not sure that the forest database should be included here. The implication is that we don't know what is out there in the forest! When I have finished I think you will agree that we know quite a lot about the forest. Whether what we know is enough, and in the right form and format, will be discussed by the next two speakers.

One question raised by the topic is the purpose of a forest database: for whom and for what are we building it? The question is illustrated in Figure 1. Although the theme of this symposium is forest investment, the analysis for investment can be made by a variety of people. I am going to concentrate on the forest manager.

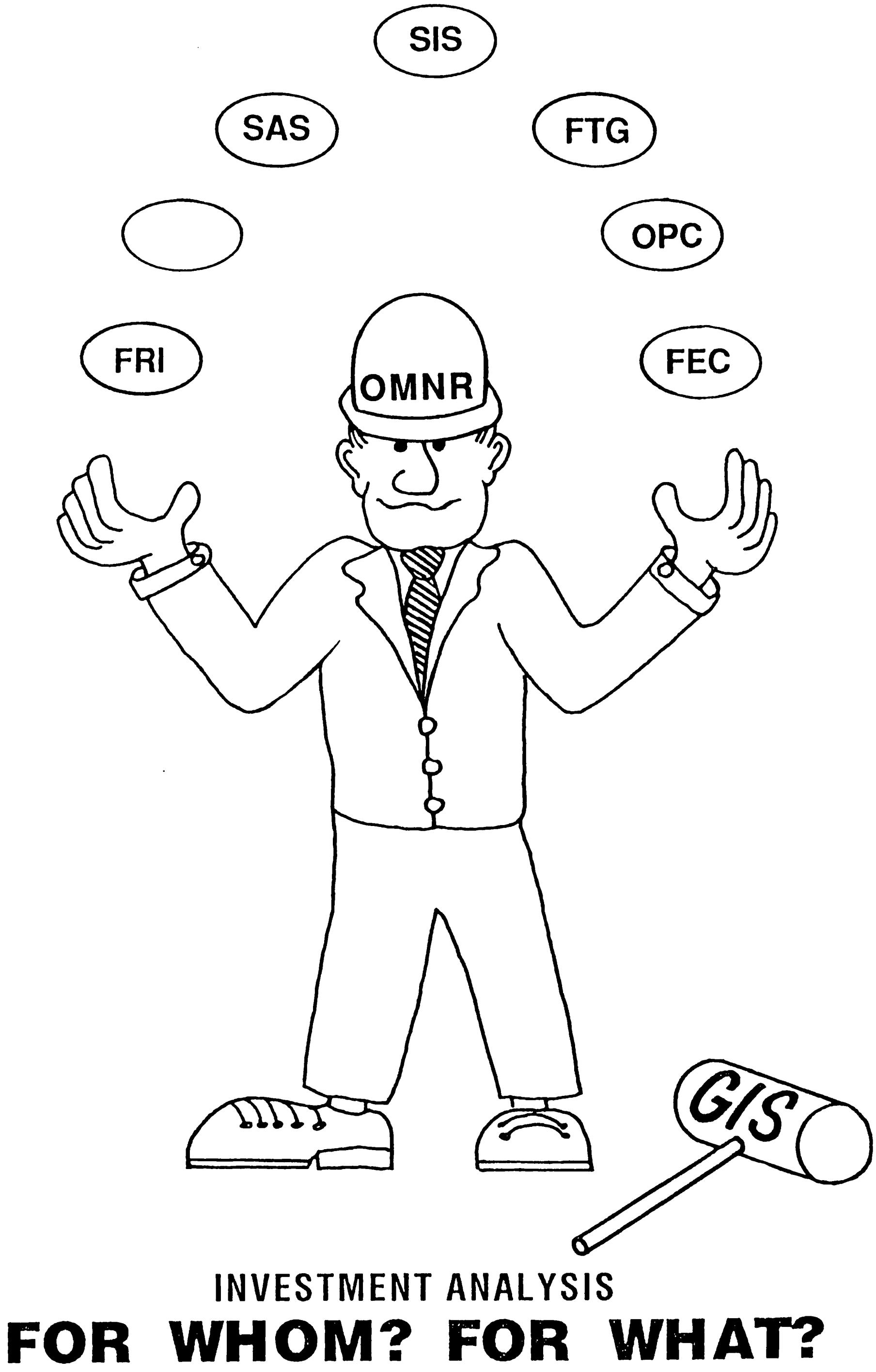

Figure 1. The purpose of a forest database

THE FOREST DATABASE

For convenience I have aggregated the various sets of data into some arbitrary groups (Table 1). The planimetry group is the underlying geographical (or georeferencing) frame upon which all these datasets are placed. If there is not a common georeferencing frame, the relating of datasets becomes a problem for the manager in any analysis.

Table 1. Basic groups of datasets in the forest database

Group name	Content description
1. Planimetry	georeferencing frame (grid), drainage, cultural features
2. Forest thematic cover	vegetation description
3. Forest history	change data (depletions/accruals)
4. Stratification of use	licences, volumes, land-use zones
5. Forest environment	soils, sites, forest management support

The forest thematic cover includes the various datasets we have that describe the trees that are growing at the time of the inventory. We have several datasets in this category. Forest history covers all the data that we have describing changes, including data used as the basis for prediction relationships. It may also include data describing the cause of the change. Stratification-of-use datasets are stratified to include ownership, legal assignments of rights and responsibilities, existing or planned land use, and associated information. Forest environment includes two types of dataset: those that describe forest sites, and those that describe special parts of the forest for forest management (seed and seedlings).

For each of the groups of datasets more details are tabulated. These tables show the title of the dataset, its major contents (or components), its form, and its software/hardware environment. An additional set of tables describes the authority and contact person for these datasets.

Planimetry

There are three sources of planimetric data for the forest database in Ontario. The first of these is the Forest Resources Inventory (FRI). More recently the Ontario Basemap (OBM) data have replaced the FRI planimetry. The Ontario Basemap data are presented in a 6^0 Universal Transverse Mercator in Basemap format, which is 10 km at 1:20,000 map scale and 5 km at 1:10,000 map scale. The OBM survey data are far more precise than those of the FRI planimetry, as they have both horizontal and vertical control. The third source of planimetric data is the Federal National Topographic (NTS) series of maps. The sources of planimetric data are summarized in Table 2. The production authority and source-data contact person are given in Table 3.

Table 2. Planimetry: datasets of Ontario and their features, software and hardware environment

Title and/or abbreviation	Features	Software	Computer
Forest Resources Inventory (FRI)	drainage, cadastre, culture, administration by township/ basemap	ARC/INFO	DEC VAX IBM PC
Ontario Basemaps (OBM)	drainage, cadastre, culture, topography by basemap	ARC/INFO	DEC VAX IBM PC
National Topographic Series (NTS)	drainage, cadastre, culture, topography by lat./long. grid cell		

Forest Thematic Cover

I have included five major datasets in this group. Some of the characteristics of each (except for the Forest Ecosystem Classification [FEC]) are given in Table 4. There is complete coverage from the southern border of the province to approximately 50° north in the northeast and 52° north in the northwest. With the exception of some Indian Reserves, the FRI forest stand maps cover all land ownership. The outputs of the system include aerial photographs, standardized reports (FRI ledgers), forest stand maps, "composite" maps, and lists of forest stand attributes. Although the data are described at the stand level, the main use is for forest management planning (as opposed to operational planning). Individual stand descriptions in the FRI should be used with due regard to the data collection/compilation process. FRI now uses OBM planimetry exclusively, and is therefore referenced to the OBM grid.

Table 3. Planimetry: datasets, source authority and contact person

Dataset	Authority	Contact
FRI[a]	Ontario Ministry of Natural Resources (OMNR) Timber Sales Branch Forest Management Information Section	John Osborn (705) 945-6680 Joe Kapron (705) 945-6688
OBM[a]	OMNR Surveys, Mapping and Remote Sensing Branch Topographic Mapping Digital Topographic Database	Roy Audas (416) 733-5090 Barry Costello (416)733-5114
NTS	Department of Energy, Mines and Resources Director Topographic Mapping Branch	Earl Shaubel (613) 996-2810

[a] Graphic (map) copies can be obtained from the Public Information Centre of the Ontario Ministry of Natural Resources (Phone (416) 965-2000).

Forest stand numbering procedures changed in 1988. With the FRI digitized, the stand number is now a 2-digit easting and 2-digit northing. The same process is being adopted in the new Silvicultural Information System to reference silvicultural projects. The stand attributes for the FRI have been in digital format for many years and are available for investment analysis. From 1988 onward the FRI-mapped data will be produced in a digital form with ARC/INFO software. As with the digital attribute data, we will distribute these to the respective users. In conjunction with field staff it is planned to keep the FRI up to date annually where the data are digitized.

Operational cruising, where it is done, provides more detailed stand and tree data on mature stands allocated for cutting in the next planning period. The data include measurements of species diameters, height, and occasionally descriptions of defect and log quality. Operational cruising **should** provide more precise and more useful stand volume data than the FRI.

The Silvicultural Assessment System (SAS) has three major subsets of data: survival, stocking and free-to-grow (FTG).

Survival data are tallies of living, artificially regenerated trees (by species). Stocking assessments are tallies of stocked quadrats; the data are recorded by species. Depending upon the system used, tree height may be tallied and a tree count made. Free-to-grow assessments include stocking, tree height, annual height increment and measures of freedom from competition. Assessments are done by "desirable or acceptable" species and the results are used to classify the assessed area

Table 4. Forest thematic cover: Ontario datasets and their features, software and hardware environment

Title and abbreviation	Features	Software	Computer
Forest Resources Inventory (FRI)	non-forest, forest land, non-productive and productive polygons, stand descriptions, tree species, working group, stand age, height, stocking, site class, volume increment, area	Map Data on ARC/ INFO Stand Data in BASIC (FRIDES)	DEC VAX IBM PC DEC VAX IBM PC
Operational Cruise (OPC)	stand detail, tree species, tree heights, diameters, defect, quality	COBOL	IBM main-frame
Silvicultural Assessment System (SAS)	tree species, count, stocking, nonsatisfactorily [sic] stocked (NSR) class	COBOL	IBM main-frame
Survey of Artifically Regenerated Sites (SOARS)	jack pine, spruce, red pine, white pine, height, density stocking, regeneration	NPL DATA-TRIEVE DBASE III	DEC PC IBM PC
Forest Ecosystem Surveys (FEC)	indicator species density, occurrence, distribution		

into one of six nonsatisfactorily [sic] regenerated (NSR) classes. In the forester's typically logical fashion -- my apologies to the Provincial Forester -- the first of these nonsatisfactorily [sic] regenerated areas is "free-to-grow"! This in fact completes the record for all lands surveyed. As with survival and stocking, the tabulated results of the FTG assessment are recorded in the SAS.

Provincial coverage of these three assessment surveys of regeneration varies. All artificial regeneration by planting is now covered by a sample survival assessment. Stocking survey samples cover all artificially regenerated areas. FTG surveys, which have only just been introduced, are done on all Forest Management Agreement (FMA) areas, and on those crown management units that use the new Timber Management Planning Manual. The FTG survey is a key factor in linking the regenerating forest to the base for calculating maximum allowable depletions (MAD). Until productive forest areas are declared free-to-grow they remain in the FRI as NSR (classes 2-6) and are **not** in the MAD base.

The fourth dataset listed in Table 5 is SOARS. This dataset is a statistical sample of artificially regenerated sites that covers the four northern regions and the Algonquin Region of OMNR. The survey covered all sites planted artificially more than 10 years ago, or seeded more than 15 years ago. Only those sites planted or seeded to black spruce (**Picea mariana** [Mill.] B.S.P.), white spruce (**P. glauca** [Moench] Voss), jack pine (**Pinus banksiana** Lamb.), white pine (**P. strobus** L.) or red pine (**P. resinosa** Ait.) were included in the survey. A complete catalogue of all regeneration projects in the survey area was the first step in SOARS. From this catalogue, sample locations were statistically selected to provide a proportional coverage by working group and regeneration type. Catalogues are available at the district level and the compiled basic data have been distributed to regional offices. Included in Table 4 is the heading **Forest Ecosystem Surveys**. All of these describe physiographic site and soils, and most of them use the vegetation component as well. These are described in more detail in the section on **Forest Environment**.

It should be recognized that all of the above datasets describe the forest at a given time, and therefore are accurate at the time of the survey. As time passes the data will typically become less precise. This is also true of planimetry. Although the planimetric data are more stable, some of their features change over time, e.g., roads, and the forest manager must take this into consideration when making any analysis.

Table 5 provides the authority, source and contact for the forest thematic cover datasets. FRI, OPC, SAS and FEC results are all available at district offices of OMNR, as are some of the computerized basic data.

Table 5. Forest thematic cover: source authority and contact person (1988)

Dataset	Authority	Contact
FRI	Ontario Ministry of Natural Resources (OMNR) Timber Sales Branch Forest Management Information Section	John Osborn (705) 945-6680 Joe Kapron (705) 945-6688
OPC	OMNR, Timber Sales Branch Management Planning Section Mensuration Unit	Dave Andison (705) 945-6669
SAS	OMNR, Timber Sales Branch Forest Management Information Section	Larry Skinkle (705) 945-6637
SOARS	OMNR, Timber Sales Branch Mensuration Unit	Jocko Mervart (705) 945-6664
FEC	OMNR, Timber Sales Branch Mensuration Unit	Peter Uhlig (705) 945-6670

Forest History

Datasets that describe changes serve three major purposes: 1) they can be used in updating original data, 2) they can enable users to make predictions, and 3) they can help users to understand why changes have occurred. With respect to purpose number 3, forest management practices can be improved and forest investments can be rendered more reliable.

Table 7 lists some of the major datasets connected with forest history. However, there are probably many other documented sets of numbers and words in circulation (or in filing cabinets) that are not included here. Obvious examples are the OMNR silvicultural guides and the Management of Tolerant Hardwoods guide. Also, there are several growth and yield studies in progress both in young stands and in over-mature stands that are mentioned only superficially in Table 7.

Stratification of Use

Seven datasets/systems that relate to stratification by use have been included in Table 8. The first five are primarily the timber aspects of forest management whereas the latter two are examples of a vast range of data pertaining to other (non-timber) uses of the forest.

The major points of contact for datasets listed in Table 8 are given in Table 9. The sixth and seventh references in Table 8 are available primarily in OMNR district offices as maps and documents.

Forest Environment

As mentioned in the Introduction, there are two major components of this group of datasets. The first group contains all the information pertaining to site, including soils data and soil/vegetation ecological data. The relatively recent **Catalogue of land resource surveys in Ontario of major value in forest management** by Pierpoint and Uhlig (1985) of OMNR serves as the best source of information on this subject. Since this catalogue was compiled in 1985, several of the datasets mentioned in it have been expanded. This is particularly true of the FEC data and SOARS data.

Three additional datasets are included in Table 10. These are PLUSTREE, the SEED inventory and the STOCK PRODUCTION SYSTEM (SPDMS). In certain forest investment decisions the data within these systems will be of importance.

Finally, in Table 11 some of the major contact people for these forest environment data are listed. Within the "Sites" category some of the original source authorities are not directly cited but two of the major contacts within OMNR and Forestry Canada (FORCAN) are listed.

Table 6. Forest history: datasets of Ontario and their features, software and hardware environment

Title and abbreviation	Features	Map data and software	Computer
Update data Depletion	FRI data, outline of area cut, date	hardcopy	
CUTOVER (FRIDES)	new stand number and stand description	BASIC	DEC PC
(SIS)	area cut by working group	DBASE	IBM PC
Update data Depletion	outline of area burnt data, residual areas	MAP DATA hardcopy	
FIRE (AFMC)[a]	fire number, FRI detail,	FORTRAN	DEC VAX
(FRIDES)	as cutover	BASIC	DEC PC
Update data Depletion PESTS (FIDS-	Forest Insect and Disease Survey (FIDS) infestation maps and reports	hardcopy	
INFORBASE)	FIDS data	INGRES	DEC VAX
(FRIDES)	as cutover	BASIC	DEC PC
Update data Depletion LANDUSE/OWNER	FRI new ownership and land-use code in FRIDES	BASIC	DEC PC
Update data Accrual FREE-TO-GROW	FRI stand detail and NSR class in Silvicultural Assessment System (SAS)	COBOL	IBM main-frame
Growth and yield data (NYT)	fully stocked (normal) species yield tables by site classes	(tabular)[b]	DEC VAX
(RED PINE)	empirical yield table by site index	(tabular)[c]	
(BLACK SPRUCE)	empirical yield table for the Clay Belt	(tabular)[d]	DEC PC
(FLAPS)	empirical yield table for 10 species in the Northeastern Region	C/UNIX	DEC VAX
(SOARS)	see Table 5[e]		PCs
(PSPs)	hardwood, jack pine and red pine		IBM PC

(cont'd)

Table 6. Forest history: datasets of Ontario and their features, software and hardware environment (concl.)

Title and abbreviation	Features	Map data and software	Computer
Stand deterioration data (CULL SURVEY)	defect, top, stump diameter and volume of species by age, site, and diameter class	(tabular)[f] ASCII	IBM mainframe
(PSPs)	volume loss in overmature black spruce and jack pine	ASCII	IBM PC
(ARNEWS)	weather, soils, tree growth, foliar status	INGRES	DEC VAX
Understanding (SIS)	detailed silvicultural project records of site treatment and results	DBASE	IBM PC
(SOARS)	treatment, survival and growth of black spruce, white spruce, jack pine, red and white pine	see Table 4	
(FLAPS)	stem analysis for 10 species related to site in the Northeastern Region	C/UNIX	many
(Algonquin)	PSP data of maple growth and yield by site and stand density	tabular FORTRAN	DEC PC

[a] The compilation of data and report writing for this system are under way. The system is not operational.

[b] Plonski's Normal Yield Tables (NYT) are computerized in tabular format in FRIROS (the report writing software of the FRI), which is written in FORTRAN and running on a DEC VAX.

[c] The red pine yield table data relationships are also described in equation form. The basic PSP data are all computerized.

[d] The black spruce yield table relationships are described in equation form. The basic PSP data are all computerized.

[e] SOARS data are all computerized and stored in ASCII files.

[f] Cull survey data, including detailed stem analysis, are on microfiche and have been computerized.

Table 7. Forest history: source authority and contact person

Dataset	Authority	Contact
FRIDES	Ontario Ministry of Natural Resources (OMNR) Timber Sales Branch Forest Management Information Section	Ken Brailsford (705) 945-6687
SIS/SAS	OMNR, Timber Sales Branch	Larry Skinkle (705) 945-6637
FIRE	OMNR, Aviation and Fire Management Centre	Dick White (705) 942-1800
FIDS	Forestry Canada (FORCAN) Forest Insect and Disease Survey Unit, Sault Ste. Marie	Gordon Howse (705) 949-9461
INFOBASE and ARNEWS	FORCAN, Petawawa National Forestry Institute FIDS Systems Development	Mike Powers (613) 589-2880
NYT	OMNR computerized tables	Ken Brailsford (705) 945-6687
(FRIROS)	as FRIDES	
Red pine and black spruce SOARS, PSPs CULL SURVEY	OMNR Timber Sales Branch Mensuration Unit	Jocko Mervart (705) 945-6664
Algonquin hard-maple data	OMNR Ontario Tree Improvement and Forest Biomass Institute	Harvey Anderson (416) 832-7264
FLAPS	OMNR Northeastern Region, c/o Regional Forestry Specialist	Dave Heaman (705) 675-4120

Table 8. Stratification by use: Ontario datasets and their features, software and hardware environment

Title and/or abbreviation	Features	Software	Computer
Timber licences	FRI or OBM map of boundary terms, timing, conditions by species, price, volume	MAP DATA hardcopy only (to be ARC/ INFO)	DEC VAX DEC PC
Woodlands Improvement Act (WIA)	FRI or planimetric map of boundary objectives, terms, timing, conditions	MAP data and files hardcopy COBOL	IBM main-frame
Wood flow system	Documentation of wood surplus/ deficits and their flow	RDM	DEC VAX
Timber scaling and billing system (TSB)	Volumes of wood scaled/billed species, cut approval, licence	1032	DEC VAX
Mill products and residues report (FIMIS)	Volume produced Mill residues by type and movement	hardcopy FOCUS	IBM main-frame
Areas of concern (AOC)	FRI or plan, map of areas for modified timber management	hardcopy only	
District land-use guidelines	Map and text of recommended land-use zones and practices	hardcopy only	

Table 9. Stratification by use: Ontario source authority and contact person

Dataset	Authority	Contact
LICENCES	Ontario Ministry of Natural Resources (OMNR) Wood Allocation Section	Ken Cleary (705) 945-6673
WIA[a]	OMNR Forest Resources Branch Private Land Forestry	Joan Brown (705) 945-6620
WOODFLOW	OMNR, Timber Sales Branch	Ken Cleary
TSB	OMNR, Timber Sales Branch Wood Measurement Section	Bob Schroder (705) 945-6643
FIMIS	OMNR, Timber Sales Branch	Ken Cleary
AREAS OF CONCERN, DLUGS	OMNR district offices	District Manager

[a] Data on the details of any WIA are kept at district offices.

Table 10. Forest environment: Ontario datasets and their features, software and hardware environment

Title	Abbreviation	Features	Software	Computer
Sites[a]				
SURFICIAL GEOLOGY	NOEGTS SOEGTS	landform, soil drainage, topography	hardcopy[b] maps	
LANDFORM	CLI	interpretive productivity	hardcopy CGIS	IBM mainframe
	OLI	forest productivity		
SOILS		Ontario Soil Survey	hardcopy	
	FLAPS	soils details	ARC/INFO[c]	DEC VAX
FEC	FEC	soils/vegetation	hardcopy	DEC VAX IBM mainframe
			ASCII/ DBASE	IBM PC

(cont'd)

Table 10. Forest environment: Ontario datasets and their features, software and hardware environment (concl.)

Title	Abbreviation	Features	Software	Computer
Plustree	PLUSTREE	plustree species, FRI stand number, tree characters, latitude/ longitude	C/UNIX DBASE III CLIPPER	Many IBM PC
Seed inventory and control		species, seed source, source type, number of viable seeds	FOCUS	IBM main-frame
Nursery stock production	SPDMS	species, 5-year fore-cast, number of trees by rotation age	compiled	DEC VAX

[a] Adapted from Pierpoint and Uhlig (1985)
[b] Some data in OMNR's Northern, North Central, and Northwestern regions are digitized on ARC/INFO.
[c] Some data in OMNR's Northeastern Region are digitized on ARC/INFO.

Table 11. Forest environment: source authority and contact person

Dataset	Authority	Contact
Sites	many--see Pierpoint and Uhlig (1985) Ontario Ministry of Natural Resources (OMNR) Timber Sales Branch	Peter Uhlig (705) 945-6670
	Mensuration Unit Forestry Canada Ontario Region	Richard Sims (705) 949-9461
PLUSTREE	OMNR, Forest Resources Branch Forest Production Section	Dave De Yoe (705) 945-6636
SEED INVENTORY	OMNR, Angus Seed Plant Manager	Brian Swaile (705) 424-5311
SPDMS	OMNR, Forest Resources Branch Stock Production Control	Sean McMurray (705) 945-6703

SUMMARY AND CONCLUSIONS

Five groups of datasets describing the supply aspects of the forest database have been outlined briefly. In view of the quantity of data described in this report, perhaps the problem posed by the topic "Tackling the Unknowns" is that of trying to determine which of the datasets is relevant to the investment analysis under consideration. The range of datasets available is diverse. These datasets have been collected not only for widely different purposes but with widely different degrees of precision. Let the user beware. Backed by a few years of personal experience in data/information management and analysis I leave you with two cautionary notes and one confession.

The two cautionary notes concern the data themselves. First, before you use any of the data mentioned in the paper, try to find out why and how they were collected. I speak from experience: I have repeatedly tried to prevent the misuse of the FRI. Second, many of the aforementioned datasets are not geographically referenced to a common base. This situation is improving gradually but one must be cautious when attempting to relate datasets georeferenced in different ways.

My confession is that the datasets describing the forests in Ontario as listed in this paper are far from complete. Most of you can cite additional data. Therefore, before you do an analysis, determine what has already been collected. Contrary to popular opinion, data collection and analysis have been going on for a long time.

LITERATURE CITED

Pierpoint, G. and Uhlig, P. 1985. Catalogue of land resource surveys in Ontario of major value in forest management. 1st ed. Gov't of Ont. 40 p. (Available from Ont. Min. Nat. Resour. Public Inf. Centre, Whitney Block, Parliament Buildings, Toronto, Ont.)

TOOLS TO GUIDE OUR DECISIONS--RELIABILITY

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Abstract--Decision making is a skill, and the reliability of tools for guiding decisions depends largely on the skill with which individuals choose them and use them. The "decision environment" in forestry is complicated by the magnitude of the temporal and spatial scales, by the number of people involved, and by the fact that all decisions are about events that have not yet occurred. Since the future is both unknown and unknowable, the creation and use of decision-making tools must be flexible. Reliability of tools should be considered in the context of the following: (i) People, not tools, make decisions and the decision environment is too complex to be captured entirely in a tool. (ii) Decision tools should concentrate on capturing a part of the cause and effect environment of the real world. iii) Decisions are about events that have not yet occurred. iv) Decisions fail most commonly because implementation in the real world does not function like the mimic in the decision tool.

Résumé--La prise de décision est un art, et la fiabilité des outils servant à la guider dépend dans une large mesure de celui qui les utilise; il importe de bien savoir choisir et utiliser ces outils. En foresterie, le cadre décisionnel est compliqué à cause de l'ampleur des échelles temporelles et spatiales à considérer, le nombre de personnes en cause, en plus du fait habituel que toutes les décisions concernent des événements qui n'ont pas encore eu lieu. Comme les décisions portent sur l'avenir et que cet avenir est à la fois inconnu et impossible à connaître, la souplesse est de mise tant dans la création que dans l'utilisation des outils de décision. La fiabilité de ces outils devrait être étudiée dans le contexte des énoncés suivants: i) C'est l'homme, non les outils, qui prend les décisions; le cadre décisionnel est trop complexe pour être saisi complètement par un outil. ii) Les outils de décision devraient mettre l'accent sur le cadre cause-effet du monde réel. iii) Les décisions concernent des évenements qui n'ont pas encore eu lieu. iv) L'échec de l'application des décisions est le plus souvent dû au fait que le monde réel ne fonctionne pas comme le modèle de l'outil de décision.

INTRODUCTION

Decision making is not a science, nor is it reducible to a scientific format. Despite the trappings hung on it, the decision-making process will always be more a craft than a science. Decision tools and their use should be viewed in this context, as suggested by Ravetz (1971, 1986). A craftsman who builds fine boats will not acknowledge that tools build boats, or willingly concede that tools play a role in the quality of the product. The craftsman builds the boat, albeit by using tools, and the **quality of the boat depends on both the skill of the craftsman in choosing appropriate tools and his skillful use of these tools.**

What is a Decision?

A decision is defined by Raiffa (1970), and experienced by a decision maker, as "choice in the face of uncertainty". A decision is a choice between two or more forecasts of the future. Each forecast is associated with a set of actions and, whether the decision maker realizes it or not, **the choice is among the forecast futures, and not among the actions.** Once the desired future is chosen, the decision maker tries to invoke a set of actions designed to cause the future to unfold as described in the chosen forecast.

What Are Tools?

Tools to guide decisions constitute the software used to organize data and convert them into forecast information for the decision maker. Tools of the type discussed in this symposium make it easier for a decision maker to decide. They also make it easier for him to learn, by comparing what was expected in the forecast used for choice with the reality that occurred when action was taken after a decision had been made.

The "decision environment" for forest investment is complex, mainly because of the enormous range of temporal and spatial scales involved. It is also complex because of the large number of human variables involved. As a result, tools can assist with only **part** of the decision process.

Most people are familiar with the problems involved in collecting data to characterize a forest, both now and in the future, for a set of alternative strategies. This is where tools play a dominant role. However, tools leave out the really complex part of the "decision environment", which includes a number of unmeasured and unmeasurable factors captured in the decision maker's understanding of that environment. These factors cannot be reduced to algorithms and are therefore not a part of the decision tools. Consider the following:

- each decision maker has his own approach to risk, and some are more averse to risk than others

- each decision maker has his own understanding of local politics, from the level of the pickup truck to that of formal political structures
- each decision maker has his own ideas about how to implement actions that follow from his decisions.

What Is a Decision Maker?

The topic of this paper is "tools to guide our decisions", and **not** "tools to make our decisions", or "our decision-making tools". The distinction is frequently lost in discussion of this topic, but **tools do not make decisions, people make decisions.** That is reality: you will find that anyone who lets a tool make decisions is incompetent and lacking in influence.

A decision maker is one who chooses between forecasts of alternative futures, and sets in motion the actions designed to direct the future towards a condition chosen from the forecasts. Hence, the decision maker has considerable influence.

A decision maker is one who takes the blame for failure. He or she shares the credit for successes, usually with a proverbial all-star cast of hundreds who were in and around the area of the decision and therefore consider themselves eligible for some of the glory. However, when things fail, the decision maker is more likely to be found standing alone. Any attempt on his part to attribute the failure to the tools used will increase the scorn of others for the "wrong" decision that **he alone** made. It should not be surprising that decision makers of influence do not allow mere tools to take over the roles.

Although it is customary to speak of the decision maker in the singular, few resource management decisions are made by a single person, and that increases the unknowns and the complexity of the "decision environment". As the number of decision makers involved in one decision increases, both individual effectiveness and individual responsibility for the outcome of the decision are diminished.

What Conditions the Reliability of Decisions?

Rarely does the process of choosing cause a wrong decision. Few decisions that are subsequently found to be wrong are shown to have been wrong choices -- most are shown to have been right choices between incomplete or wrong forecasts!

When a decision is proven to be wrong it is commonly because the cause and effect forecasts were faulty. The literature on decisions and policy suggests that most decisions prove to be wrong because they were not implemented in reality as they were implemented analytically by the decision tools. Pressman and Wildavsky (1971) have written a delightful analysis of these problems in their book "Implementation" -- How great expectations in Washington are dashed in Oakland". Wildavsky's "Speaking truth to power" (1979) and Michael's "On learning to plan -- and planning to learn" (1973) offer definitive descriptions of this problem.

Decision makers are not necessarily being stupid when they ignore the guidance offered by high-powered decision tools. Although they may seem to be ignoring good advice, often they know that the decision tool is faulty in the way that it depicts relations between cause and effect or in its omission of critical factors of the type often referred to as "soft".

The fact that resource management decisions are sequential is also a frequent cause of unreliability. For example, a decision to plant a cutover leads inevitably to a decision about shrub control in the same area, and is soon followed by the need for a decision about density control, then one about protection, and so on. In each case, the decision will compare future performance of the stand after different possible actions, and whatever action is taken reduces the options with respect to future decisions.

Characteristically, each step in a decision sequence involves an incremental investment that will enhance or protect investments at previous stages. Walters (1975, 1986) examines how each choice in a sequence reduces the available options, and invokes a pattern of attempting to protect an accumulation of previous (sometimes bad) investments.

Sequential decisions are complicated when a number of decision makers must agree on each step in the sequence. A "decision line" that is acceptable to all decision makers for the first three steps in a sequence may be unacceptable to one of them for the fourth step. When that possibility is not foreseen, it is possible to arrive at the fourth decision step in the sequence only to discover that no options acceptable to all the decision makers remain open. This situation results in a collapse of the collective decision process.

Who Judges Reliability?

The context of reliability of tools is even more complex than the context of their use in guiding decisions. A tool is not reliable just because it does the arithmetic correctly. The issue is not whether 2+2=4, but whether 2 and 2 should be added in the first place. Reliable performance of a tool for guiding decisions is **not** the same as reliable performance in making decisions. Reliability of tools used in decision making depends more on the skills of the decision maker in choosing and using them than it does on the tools themselves.

In the examination of tool reliability the crucial factor is that decisions are future-oriented. Although our society emphasizes the importance of being factual (something that concerns the present or the past), **all decisions are about events that have not yet occurred.** Therefore, all decisions must be taken in the absence of facts about the outcome of various alternatives.

The future orientation of the decisions is important when one speaks of "validation" of tools, a term that frequently puzzles decision makers. How, they ask, can one "validate" a tool for situations that have not yet occurred? The decision maker wants to forecast the future reliably, not review precisely events that have already happened.

Since decision making is a skill, the definitive judgment of the reliability of tools must lie with the decision maker. To these judges, reliability of a tool centers on two features. First there is the matter of **how accurately the tool reflects the structure of the specific decision they face now**. Decision makers show a powerful preference for tools structured to their specific problem. Few decision makers believe that their problem is like that of anyone else. Consequently they show little interest in general (all-purpose) tools. They are interested, however, in models that are easily customized to fit their problems and express those problems (and their solution) in terms they can readily understand.

It is curious that, to achieve reliability in the eyes of the user, a tool for guiding decisions must avoid trying to capture the entire problem of the decision maker since this is not possible -- **success for the toolmaker lies in depicting an identifiable part of the total picture accurately and in a meaningful format.**

A good test of tool reliability as it relates to the structure of the problem is to examine how decision makers use the available tools. There are three levels at which tools for guiding decisions are used:

(i) Decision tools, and the copious output therefrom, are frequently used as weights to hold doors open or closed, i.e., they are not used at all. The tools are in evidence around the "decision environment", and the decision makers may even exercise the tools occasionally, much as one might walk a dog, but the tools have no influence in the decision process.

(ii) Decision tools are often used conveniently to verify a choice that has already been made. That is, the tools do not guide the decision in any sense, but the fact that they can be exercised to give support to a decision taken on other bases can be useful in explaining choices, especially political choices. This process is not without value when it helps decision makers understand the factors involved.

(iii) There are cases in which tools are used to inform decision makers so that they can make intelligent decisions. In this sense, the tools guide the decision process.

It is usually possible to discover at which of these three levels decision tools are being used, and it is safe to assume that the user does not consider the tool a reliable and useful analog of his problem if it is used only at the first two levels.

The second major feature influencing the reliability of a tool is that of how well the tool reflects the future orientation of the decision process. **An overwhelming concern of the decision maker is the degree to which tools accurately reflect the way in which cause and effect relationships will operate in the future world in which his decision will be implemented.**

Decision makers earn their living by operating "action levers" that influence cause and effect. They do not believe that the future will repeat the past because their business is to exert control over the way in which the future evolves. Decision makers distrust projections of past performance into the future **in any area in which the decisions they make can have an influence.**

There is danger here, in that decision makers commonly do not comprehend the entire cause and effect picture. Their expertise tends to be in evaluating cause and effect relationships in markets and command structures. They are generally less well versed in the biological responses that can be entrained by an action. Hence, a decision maker may accept a tool that is accurate in terms of market response without realizing that it is inaccurate biologically, or he may reject a tool that contains a poor representation of market forces but is biologically accurate.

In my experience, when a decision maker believes that an action intended to achieve a certain outcome in the calculations of a decision tool would not achieve that same outcome if implemented in "his world", he will not consider the tool a reliable part of the decision process. Both Wildavsky (1979) and Michael (1973) note that a common reason for a decision maker to depart from the guidance given by a decision tool is his distrust of the accuracy of the cause and effect relations therein.

For such reasons, as well as the personal understanding referred to earlier, most decision makers will resist using a tool when the probability of events is built into a forecast, and when they must accept those probabilities, and the associated risk of a bad decision, as determined by the tool builder. For instance, the decision maker has his own feeling for market trends, with particular reference to how these influence the outcome of an investment decision. This is part of the knowledge that got him to the decision table. He is unlikely to lay that knowledge out for others to use, and he will insist on relying on his feelings in decision forecasts rather than accept numbers provided by a "tool".

Such an approach reflects personal reaction to uncertainty. A good decision tool will not embody such a reaction, but will characterize uncertainty in its forecasts in a manner that allows the decision maker to apply his feel for the situation in an intelligent manner.

Reliability depends partly on the tools themselves, but mostly on **who** uses them and **how**. The "who" and the "how" cannot be controlled by the toolmaker!

Hence, it is difficult to build reliability into a tool for guiding decisions. Note that, even after the fact (when a series of actions associated with one choice is implemented), only one possible outcome can be known (the one caused by actions following on the decision), and the results **that might have been** from all other decisions remain unknown, and conjectural. Hence, tools should be of a nature that encourages the user to adapt over time, and minimizes the possibility of surprise, as discussed by Holling (1986).

In terms of reliability, the choice involved in a decision is between things that cannot be known at the time the decision is taken. The unknowns and the risk are not in the act of choosing, but rather in the forecasts that form the basis for choice. Therefore, a tool cannot be known to be reliable in advance, no matter how elegant it may be.

Tools never will be able to mimic the intellect of the decision maker or handle the type of experiential information the decision maker brings to the process. Eventually, artificial intelligence will make a portion of the intellect of a few decision makers available to the rest of us. This will no doubt help with bureaucratic and other formula decisions, but do not hold your breath waiting for meaningful artificial intelligence in the field of forest investment. Incidentally, to avoid the negative connotations of the phrase "artificial intelligence", the current term for such systems is "knowledge-based". It makes one wonder what the other kind of decision is supposed to be.

CONCLUSIONS

There is a tendency in forestry to handle the unknown timidly, in cautious little steps. Some foresters believe that if decisions are deferred long enough, study can make the unknowns known. That does not apply to the things of most concern in decision making -- namely things in the future. The best way to handle unknowns is aggressively -- the way to find out what is under a rock is to turn the rock over. Sometimes the result will be a pleasant surprise and sometimes not so pleasant, but you cannot know which until you take a step on faith. The faith required here is not of the Polyanna kind that nothing bad will happen, but rather a faith that you are acting in a measured manner, and that you are prepared to recognize and handle things you uncover **if you do the uncovering yourself**, rather than wait for things to surprise you by crawling out on their own.

Finally, here are some guidelines, for both toolmakers and tool users, for the reliable use of tools to guide our decisions.

(i) Let the decision maker decide. Decision guides should be just that, and not decision rules. Do not try to use a decision tool to preempt the role of a decision maker, unless you personally take responsibility for the decision outcome including, especially, failure.

(ii) Look for errors in forecasting, not in exercising choice based on forecasts. A decision is a choice made between alternative futures with the intention that action will be taken to try to make the future unfold in a chosen manner. There is a higher risk of error in the **forecasting** of alternatives than in the **choice**.

(iii) Decision guides should not give "the answer"; rather, they should facilitate exploration of the effects of actions of interest to the user, if he is to be a true decision maker.

(iv) Decision guides should allow the user to explore risk. Aversion to risk is a personal characteristic that should be expressed by a decision maker, and not by a model. The decision maker needs tools that display the inherent uncertainty in the forecasts and draw his attention to forecast errors that could be damaging to him.

(v) Avoid freezing the decision-making process into a cookbook format. There is always a danger that tools to guide our decisions become bureaucratic weapons to gain control over decision making. In dealing with an unknown and unknowable future, a bureaucratically constant approach reduces adaptability and reduces the chance of being "right" as the future unfolds.

(vi) Do not fear unknowns. There never will be a time when everything necessary for a safe decision is known. The future is unknowable except by experiencing it, at which time "it" has become the present! Use the best available data and the best available tools, **and be ready to change both as better ones appear.** The best way to learn is to make decisions, and to examine the outcome in relation to the forecasts used in the decision process. Put yourself in the best position to learn from the experience of each decision taken, and go for it!

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WRAPUP STATEMENT

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Yesterday morning, Ted Boswell, in his keynote address, mentioned that he was off to Brazil to see the Eucalyptus forests. They are worth seeing.

Over the past 15 years Brazil has applied forestry policies -- including fiscal incentive programs -- to establish 6 million ha of eucalypt and pine plantations. The scheme has been so successful that Brazil, once a pulp and paper importer, is now earning more than $600 million U.S. annually from pulp and paper exports.

Chile has successfully employed economic incentives, including special tax laws and subsidies, to establish 1.1 million ha of pine plantations. The country is now entirely self-sufficient in forest products and is earning $350 million U.S. annually from the export of logs, sawn wood, pulp and paper.

Nepal, the tiny Himalayan kingdom of 17 million people, is the fourth-poorest country in the world. Thanks to Chinese technology, Nepal now has two paper mills, the furnish for which is 100% sabai grass and rice straw. The rotation age is four months.

Ted also mentioned 'prime sites'. He said that, wherever in the world there are prime sites, that's where the dollars will go. This is not exactly the type of prime site we had in mind! Enter the global forest economy.

The United Nations Food and Agriculture Organization's Tropical Forestry Action Plan for 1987-1991 calls for the expenditure of $5.3 billion U.S., 25% of which is targeted for forest management for industrial uses. About half of this investment will come from bilateral and multilateral development assistance agencies and half from national governments, small farmers and the private sector.

Our keynote speaker also referred to stability, realism and self-confidence, about rising above the critics and implementing good forest management, and about how we should sell ourselves to "gain the heights".

When it comes to selling ourselves -- at least to the public -- we don't seem to do it very well. As Ted spoke I thought about the environmental assessment hearing downtown. The public has not turned out in record numbers to hear what we have to say.

I got the impression that what we were being told was to improve our public image -- not so much by changing what we do, but rather by changing our attitude and the way in which we project ourselves to the community at large.

Of course that is an investment -- not in dollars but in energy and discipline. The future benefits could be substantial, however.

I believe that much of the good solid work done in forestry is completely unknown to the public. Since the public happens to be the landlord, and through elected representatives controls the treasury from what funds are obtained for forest investment, more of an investment of our time and effort in improving public awareness would probably be beneficial.

Forest investment requires decision making. Decision makers have little choice but to make some assumptions about the future. Such assumptions should be based on a rational appraisal of possibilities. To make such an appraisal, data, tools and information are needed.

In his book "The Age of Discontinuity", Peter Drucker put it this way: "The future is always guerrilla country... in which the unsuspected and apparently insignificant derail the seemingly invincible trends of today." Drucker described the derailers as four major discontinuities, namely:

- new technologies
- shifts from international to global economics
- the political matrix of social and economic life
- knowledge.

This is pretty much the kind of thing we have been talking about over the past day and a half.

What should we be taking into account today that will help us to improve our decision making about future courses of action? In discussing the decision-making process several panel members pointed out some of the realities we must face.

Changing markets and products such as were described by Jim Kingston exacerbate the problems related to forest investment decisions. John Osborn warned us this morning that the five groups of data sets he described were collected for widely different purposes and with widely different levels of accuracy. Similarly, Doug Walker pointed out that the major impediment to the use of models in support of forest investment decisions is the lack of local data upon which to base accurate forecasts. He did agree, however, that considerable information is available that in many cases could be useful.

The structures or institutional arrangements referred to include the timber management planning process, particularly the process for public participation, regional planning strategies and the timber production policy. With respect to the latter the question was asked: "How will data from industry be incorporated into the process?"

In response, John Goodman pointed out that six discussion papers related to the timber production policy will be distributed for comment to industry and other users. Non-consumptive uses and environmental issues related to Ontario's forests are receiving increasing attention today. That is fair, but what it means is that an investment in people and resources will be a continuing requirement of both industry and government, to ensure that the principal forest user maintains its position as a major generator of government revenues and employment opportunities.

The Ontario Forestry Research Institute is, as we heard yesterday, just slightly beyond the conceptual stage. The province is in, industry is in, the federal government is not. Financial support is being sought. Underlying this initiative is a perceived need for much closer links between the researcher and the decision maker and user. In meeting that need the institute will have to address the problem of the lack of current research at the stand and forest level -- an investment need referred to on several occasions yesterday.

One form of investment not dealt with during our proceedings was related to human resources. Today's foresters must be prepared for challenges to their role as forest managers. Other sectors of society are seeking active roles in this task which, until now, has virtually been the domain of the forester alone.

Young foresters today must be given the opportunity to develop their abilities so that they can deal effectively with the array of issues with which they will inevitably be faced. This means, for example, that universities must reexamine their academic programs in light of the kind of graduate forester that will be needed in the future.

In 1928, Max Born, physicist and Nobel prize winner, said: "Physics, as we know it, will be over in six months." Stephen Hawking, in his recent book "A Brief History of Time", says that the reason Born was wrong was the subsequent discovery of the neutron and nuclear forces, a statement that, in a way, takes us back to Drucker's idea about the "knowledge" derailer.

We can say with some confidence that forestry, as we know it, will **not** be over in six months. It will **change** markedly, however, in the next few years. The nature and extent of the investment that we, as foresters, are prepared to make in forging links with the community at large and in taking into account all of the values of forest land will dictate the efficacy of our role in a changing world.

SESSION VI: Poster Session

"PLANT PC": SIMULATION OF ARTIFICIAL FOREST REGENERATION IN ONTARIO ON PERSONAL COMPUTERS

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A computer simulation model has been developed to aid forest managers in Ontario with their forest renewal problems. The model treats the regeneration process as three separate but interdependent phases: 1) stock production, 2) storage, and 3) plantation management. During each phase, growth and survival of seedlings are simulated according to empirical submodels that reflect the effects of various biological factors as well as management options. Large data sets from several greenhouse/nursery operations and experimental plantations established in northern Ontario were used to construct predictive models. Such regression models were derived by first identifying factors affecting stock production and plantation performance by means of stepwise regression procedures, and then developing nonlinear models expressing seedling growth and survival as functions of time, management options and silvicultural practices. The model simulates various regeneration options according to the users' choice. It compares and optimizes the results on the basis of a Regeneration Cost Effectiveness Index (RCEI) which, in effect, combines the cost of production with growth, survival and the quality of the resulting "free-to-grow" stand. The model is written in the Turbo PASCAL language and runs on IBM PC-compatible computers.

FIDME-PC: FORESTRY INVESTMENT DECISIONS MADE EASY ON PERSONAL COMPUTERS

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and

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Most forestry investments are long-term by nature and therefore subject to much risk and uncertainty. In the case of forest renewal investments in particular, it is essential that they be chosen from among the most promising alternatives possible. To evaluate and screen out investment alternatives with relative ease and greater precision, forest managers need a technique that not only enables them to predict the costs of production and rates of return but also indicates the likelihood of their being achieved.

FIDME-PC was developed to serve the above need. Up to four investment alternatives may be compared by using any one of the following four economic criteria: 1) cost effectiveness, 2) benefit:cost ratio, 3) present net worth, and 4) internal rate of return. The input estimates for the model may be expressed in the form of either point or subjective probability estimates. Simulated results will indicate the probability that one investment might differ from others. Therefore, the forest manager will be able to choose, with a known degree of confidence, between investment alternatives.

FIDME-PC is written in the Turbo PASCAL language, which may run on an IBM PC-compatible system. A diskette copy of the program listing, input examples and an installation guide may be obtained from the authors.

SPATIAL ANALYSIS IN

TIMBER MANAGEMENT PLANNING

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and

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The objective of this thesis was to develop a spatially sound design tool for timber management strategy. Long-range timber management modeling systems were identified as being limited by their inability to perform large-scale spatial analysis. Large-scale spatial analysis capabilities, realized with the introduction of a Geographic Information System (GIS), allow resource managers to consider the spatial distribution of treatments, haul costs and timing of access (termed the "spatial problem"). Three candidate modeling systems were evaluated for integration with large-scale spatial analysis; "Timber RAM" was chosen because of its transferability, ease of modification and sufficient constraint capabilities. The mathematical structure of a modified Timber RAM system was described.

A management planning algorithm was proposed as a means of developing spatially sound treatment schedules. The heart of the management planning algorithm was the HAULCOST.CPL routine, which attached haul cost and timing of access attributes to individual stands in a forest property. These attributes were used in stand class aggregations to perform the modified Timber RAM analysis.

The management planning algorithm was implemented for a case study forest. Results of the case study were evaluated with respect to the ability of the management planning algorithm to address the spatial problem and the feasibility of implementation in an actual planning situation. The management planning algorithm was able to produce spatially sound harvest schedules, and thus achieved the stated objective. Practical implementation was considered to be feasible for those organizations maintaining an ARC/INFO GIS and data base.

AN APPLICATION OF EXPERT SYSTEMS IN WILDLIFE:

FOREST STAND PRESCRIPTION ADVISORS FOR DEER AND GROUSE

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An expert system is a computer program that emulates the decision-making logic of human experts in solving domain-specific problems. Such software can be used to capture the knowledge and experience of experts for management applications. Expert systems are appropriate for applications that require an expert's knowledge, frequent decisions, and heuristics to solve. For example, they have been applied to problems involving classification, valuation, prediction, or recommendation. Expert systems have three elements: an interface (linkages to the external environment), an inference engine (computer algorithm for reaching a conclusion), and a knowledge base ("canned" expertise). We developed two expert system wildlife habitat advisors -- one for white-tailed deer and one for ruffed grouse. Each evaluates characteristics of forest stands and recommends a silvicultural prescription to benefit the respective species. The fundamental aspect of creating an expert system is the development of the knowledge base. We used the following steps to create the knowledge bases: literature review, organization of knowledge, identification of information available for decision-making, creation of a decision tree, and formation of rules for the knowledge base. We found the most difficult step to be creation of the decision tree. We concluded from our experience in developing the forest stand prescription advisors for white-tailed deer and ruffed grouse that expert systems provide an excellent vehicle for fostering the evolution of knowledge (research), communication of knowledge (technology transfer), and application of knowledge (management).

THE STATUS OF
THE GREAT LAKES FOREST GROWTH AND YIELD COOPERATIVE

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and

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The Great Lakes Forest Growth and Yield Cooperative (GLFGYC) is designed to encourage the development of forest growth and yield information in the Great Lakes region of the United States and Canada. Its primary objective is to foster the collection, pooling, and synthesis of such data within the region and to provide a strong data base for developing and refining forest growth and yield prediction methods. It also attempts to identify priorities, provide direction, and encourage both the development of new growth and yield models and the improvement of existing models. Several specific projects are planned for the first two years of GLFGYC. Although emphasis is on making the best use of existing data, GLFGYC is also installing many permanent forest growth plots near weather stations. These plots will be used to monitor the effect of changing climatic patterns, improve growth prediction, and understand the effects of acid deposition.

To improve the use of existing data, GLFGYC will develop guidelines for installing, maintaining, measuring and reporting permanent plot records. GLFGYC is also developing a data storage and retrieval system for maintaining endangered data sets, and will organize a complete catalogue system to describe other available data sets that may be too large for it to maintain. Although much work on growth and yield has been done in the Great Lakes Region, simple, empirical yield equations and tables, especially for young stands, are needed. Such equations will be developed for the major forest types of the region.

Membership has been solicited from public organizations (local, state/provincial, and federal in both the United States and Canada), private industry, and various universities. Currently, 7 universities, 12 government agencies, and 6 private organizations participate in GLFGYC. The cooperative, with headquarters at the University of Minnesota, was established through a grant from the Legislative Commission on Minnesota Resources and support from existing projects of the University of Minnesota Agricultural Experiment Station, the Minnesota Department of Natural Resources, and the USDA Forest Service's North Central Forest Experiment Station.

DECISION SUPPORT FOR TIMBER HARVEST SCHEDULING:

AN INTEGRATED APPROACH

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An integrated microcomputer forest planning system has been conceptualized and is now being made operational. The system includes DTREES, an automated prescription writer, and DUALPLAN, a forest management scheduling model based on the Hoganson-Rose approach. Data input and output interpretation are supported by two additional components, the TYDAK-Spans geographic information system, and a database management system. The total system permits the user to simulate a sequence of management alternatives, produce an optimal harvest schedule, display and analyze spatial aspects of harvesting, and generate useful management reports and operational plans. All modeling can be done at the level of an individual stand; there is no need for data aggregation. Demonstrations of the prototype system and the type of data and information management systems that are under development are provided.

TWIGS: AN AID TO FORESTRY INVESTMENT ANALYSIS

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Forestry investment analysis requires estimates of both financial and timber resources. TWIGS, a microcomputer program, aids in the analysis of management strategies and the computation of several measures of economic performance for the associated cash flows. TWIGS was developed for use in forests of the north central United States. Yields from mixed species, all-aged stands and pure, even-aged stands can be predicted.

Management in TWIGS is menu-driven, so that it is possible for the user to apply nearly any cutting method desired. Graphical stocking guides provide a useful framework for determining how to treat a stand. Volumes for sawlogs, pulpwood, and residue are calculated by species group. TWIGS can be used to organize and develop a cash-flow table and to set stumpage rates for various products and species. Six measures of economic performance quantify the return from the simulation: net present value, equivalent annual income, soil expectation value, benefit:cost ratio, payback period, and internal rate of return. Information is also provided to help the user evaluate the risk associated with the management alternative.

JACK PINE STORABILITY IN ONTARIO

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Staff of the Mensuration Unit of the Ontario Ministry of Natural Resources have studied the long-term on-site storability of mature and overmature jack pine stands in Ontario. Forty-seven permanent sample plots in north central and northwestern Ontario, for which 30 years' worth of data were available, were remeasured and analyzed for this project. Twelve temporary sample plots were also set up in northeastern Ontario. In all, 400 individual trees were cut down and sectioned for stem analysis. Project results indicate that there is no significant decrease in gross total volume production in jack pine stands in Ontario up to the age of 180 years. However, cull becomes an important factor in jack pine stands more than 80 years old. Cull appears to increase at an accelerating rate in mature and overmature jack pine stands and the rate of increase appears to be significantly higher in jack pine stands growing on shallow soils.

MAPLE 1: A SUGAR MAPLE GROWTH AND YIELD MODEL FOR ONTARIO

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Using data from 46 permanent sample plots, staff of the Mensuration Unit of the Ontario Ministry of Natural Resources have developed a preliminary growth and yield model for sugar maple stands in central and southern Ontario. This model runs on an IBM PC-compatible computer with Lotus 1,2,3. The user enters stand location, stand dominant height, and tree frequency by diameter class. The model produces, in hard copy and graphic form, information on current stand conditions and projected stand parameters. Output is presented by diameter class, and includes stem frequency, average height, gross total volume, gross merchantable volume, and board-foot volume. Stand projections have been tested against a subset of the data, and an accuracy of ±10% or better is indicated for all projected parameters over a 20-year period.

A METHODOLOGY FOR EVALUATING THE IMPACT OF THE JACK PINE BUDWORM ON JACK PINE WOOD SUPPLY

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Each year the finite forest resource in Canada is affected by insect activities. One of the negative impacts is the loss of millions of cubic metres of wood. Evaluating the significance of the volume loss to society is an important forest management activity. Quantitative solutions can be obtained through the use of wood forecasting models.

The wood forecasting model chosen for the evaluation should be based on two components. The first component is the expected wood supply forecast with and without insect infestations. This provides the decision maker with an estimate of the damage (the value of the difference of the expected wood supplies). If the expected wood harvest is at risk, the decision maker can place an upper limit on expenditures for pest management. The second component is the forecast of the reduction of damage and its effect on wood supplies as a result of the use of alternative pest management strategies. The potential for increasing the wood supply through forest management strategies is a factor that should not be excluded from the model. If exceeding the upper limit of expenditures for pest management is acceptable, this cost or the cost of achieving other objectives can be estimated.

A simple wood supply model that estimates the damage caused by jack pine budworm (**Choristoneura pinus pinus** Freeman) in jack pine (**Pinus banksiana** Lamb.) forests of Ontario is exhibited. The model offers the choice of "oldest-first" or "opportunity-cost" harvesting schedules, predetermined allowable cut or model-determined long-term sustainable yield, yield source, damage estimates, up to five product types, user-estimated stumpage prices, and type of data output. Case study analyses are available on request from the author.

THE EVALUATION OF FOREST MANAGEMENT PRACTICES IN TERMS OF END-PRODUCT VALUE

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The level of silvicultural management is rising dramatically in Canada. In the past five years over $1.2 billion has been invested through the federal-provincial forestry agreements alone. It is generally assumed that the larger volume of wood produced from these investments will result in proportionately greater value, but for the most part this is not the case. As growth is stimulated the proportion of lower-quality juvenile wood in a tree increases, thereby reducing its suitability for a wide range of products.

A new approach to the evaluation of silvicultural investments in terms of end-product value has recently been developed for coastal Douglas-fir (**Pseudotsuga menziesii** [Mirb.] Franco). FORINTEK Canada Corp., in cooperation with the Pulp and Paper Research Institute of Canada, the British Columbia Ministry of Forests, and the forest industry, has examined not only the basic wood properties of this second-growth resource, but also the product yield and quality of this material for pulp and lumber.

This major effort, known as the Douglas-fir Task Force, consisted of nine integrated studies and included an examination of the effects of silvicultural treatments on both volume production and wood quality. The result has been a system of models, named SYLVER, consisting of a series of computer simulations that pass the output from a stand simulation model (TASS) through a bucking and sawmill conversion model (SAWSIM). Product and grade information then become the input to a financial analysis model (FAN$Y), which is capable of assessing a variety of silvicultural treatments in relation to the predicted product revenues.

With the SYLVER system it is possible to input a variety of variables such as site class, logging chance and distance to the mill, and to determine the optimal stocking density and rotation.

GLFC-FORMAN VERSION 1.0

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GLFC-FORMAN Version 1.0 is a VAX 11 FORTRAN-coded version of FORMAN Version 2.1 as developed by E.C. Wang (New Brunswick Executive Forest Research Committee Inc.), T. Erdle and T. Rousell (New Brunswick Department of Natural Resources and Energy). GLFC-FORMAN was developed in conjunction with a continuing study by the Economics Unit at the Great Lakes Forestry Centre, designed to assess the economic impact of large-scale insect defoliation damage (e.g., by spruce budworm). GLFC-FORMAN is an interim product of that study and, as such, is available to anyone with access to a VAX computer that supports a VAX 11 FORTRAN compiler. The FORMAN model is a deterministic, forest-level inventory projection model designed to portray forest development over time in relation to given yield functions (i.e., yield curves) and predetermined levels of harvest, regeneration and spacing.

CANADA-ONTARIO FOREST RESOURCE DEVELOPMENT AGREEMENT:

RESEARCH, DEVELOPMENT AND APPLICATION

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The Canada-Ontario Forest Resource Development Agreement (COFRDA) is a five-year, $150 million initiative funded equally by the governments of Canada and Ontario. The $6.5 million Research, Development and Application Program is funding projects that reflect priorities established by the Ontario Forestry Research Committee. Sixty research projects undertaken by universities, consultants, forest companies, the Ontario Ministry of Natural Resources, and Forestry Canada are contributing to a productive future for Ontario's forests. Areas of research include tree improvement and stock production, regeneration, protection, tending, and resource allocation.

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