The Potential Economic Impact of Biotechnology and Related Research on the Forest Sector

by

F.L.C. Reed¹

Abstract

The Canadian forest sector is at a critical juncture in maintaining its competitive position internationally. One reason is the difficulty that we are experiencing in holding the line on the costs of timber and its processing. The expenditure on silviculture alone is often in the range of 10-20% of the cost of delivering roundwood to manufacturing plants. The entire forest community is counting on forestry science, and espe-

cially biotechnology, to enhance industry viability and provide solutions to problems with environmental quality. However, the funding of forestry R&D has always been handicapped by our inability to argue persuasively for science budgets. The central theme of this paper is that the application of biotechnology and other science to forestry certainly does pay. A synthesis of traditional and newer approaches to benefit-cost analysis is recommended to assist science managers in making their case for financial support.

Introduction

The principal objective of this paper is to discuss the potential economic impact of research, especially in biotechnology, on forestry and the forest industries of Canada. While biotechnology research in forestry concentrated initially on growing and protecting trees, the scope has now been extended to include processing technology and effluent treatment. The importance of biotechnology, however, is still most often related to the availability of a competitive raw material supply for our wood processing plants.

The forests of Canada are the nation's most valuable natural asset. The paper begins, therefore, with a few facts on the importance of the forest sector and a brief sketch of the supply-demand balances expected for softwoods in the years ahead. Then the discussion turns to where we are in Canada today in measuring the impact of biotechnology, not only in growing trees but in processing as well. That will set the stage for an examination of the analytical options available for assessing the impact of science expenditures. The main section gives some indication of the practical results anticipated from biotechnology and of the best way to marshal the evidence.

The central message is that the application of biotechnology research to forestry certainly does pay, and that a more systematic and rigorous analysis of benefits and costs will show this to be the case. That is not to claim that biotechnology is something magical, like the answer to the alchemist's dream, but there is mounting confidence from the evidence now on record to justify aggressive research programs in both forestry and forest products.

Usage of the term biotechnology in this paper follows the broad definition recommended by the Science Council of Canada in a 1984 report:

"Biotechnology in contemporary usage refers to a range of new techniques coming from the life sciences (especially microbiology, biochemistry and genetics) and biochemical and chemical engineering".

Importance of the Forest Sector

To begin with, two-thirds of the combined area of the 10 provinces are classified as forested. In historic terms our economy relied on the forest resource as the mainspring of early commercial and industrial development. The forest sector later evolved into our single most important generator of employment and income. Approximately one million families owe their livelihood directly or indirectly to the forest industry. In the 1950's Canada became the largest exporter of manufactured wood and wood fibre products. We are first in production of softwood lumber, newsprint and wood pulp and account for 25% of world trade in manufactured forest products (FAO 1986a).

This reliance on export markets underlines the vital importance of having a competitive wood supply. We shall sell approximately \$24 billion worth of forest products to foreign customers this year, out of a total selling value of shipments of nearly \$40 billion (Statistics Canada). Every region has an important forest sector. British Columbia shipments will reach about \$13 billion this year, Quebec and Ontario will account for \$10 billion each, and the remaining \$7 billion in sales is distributed across seven other provinces.

A healthy forest is of interest for many other reasons as well. This rich and varied resource contains the sources of our rivers, is the habitat for wildlife and fish, is the backdrop for a multi-billion dollar recreation and tourism industry, and has a major impact on climate. In fact, the forest makes a positive contribution to the lifestyle of every Canadian, whether or not we are conscious of its pervasive influence.

It should follow from these facts that Canada is also the most diligent in forest renewal and protection as well as first in forestry science, but such is not the case. Perhaps this will be true some day. Meanwhile we should be responsive

¹NSERC/Industry Research Chair, Faculty of Forestry, University of B.C., Vancouver, B.C., V6T 1W5

to visionary leadership that seeks to carry us forward in this direction.

Timber Supply

World consumption of industrial roundwood is growing at 2.5% annually, according to the FAO (1986b). Our ability to maintain the current share of these international markets depends in the first instance on the success we achieve in accelerating forest growth and yield while maintaining high quality and low cost raw material. Unfortunately, the prospects for expanding Canada's roundwood harvest are not bright if we stick to the status quo in forest renewal. We are now harvesting about 170 million m³ of softwood logs annually, compared with a calculated annual allowable cut (AAC) of slightly less than this amount.

Meanwhile, there is an increasing awareness that timber supplies are tightening in some regions. Several provinces are spending less on silviculture than required to sustain the harvest at existing levels, even though timber supply deficits are unacceptable, not only to several hundred forest-based communities in Canada but also to those in upstream and downstream activities relying indirectly on timber utilization. The answer is to remove this threat of timber deficits by making the necessary changes in forestry policy and performance without delay.

Moreover, the same kind of over-commitment of the softwood forest is now readily apparent in the US Pacific Northwest (Schallau 1988), and a recent report of the US Forest Service (1988) raises the prospect of supply problems in the South. Some of this is due to the wilderness movement which has recently prompted the withdrawal of millions of hectares of prime timber land from industrial reach across North America and indeed around the globe.

Softwood plantations in New Zealand, Chile and other countries are unlikely to cover the projected shortfall (Reed 1984). This situation helps to explain the growing use of aspen and poplar in North America, of eucalypt plantations in the southern hemisphere, and of the increasing acceptance of the CTMP process and other technologies that promise to stretch the raw material supply. There is also the continuing trend toward closer utilization of fibre in the woods and in the mills. Timber stands once thought to be economically inaccessible for a variety of reasons are now being fought over by manufacturers.

In short, a competitive fibre supply can no longer be taken for granted. We must build a more effective partnership between science and the forest sector as the first step in meeting the challenge of stable growth in the raw material base. At the same time we must examine every means to pace the world in wood processing technology to meet the demands of society for better bleaching and effluent systems as well as for more acceptable wood preservatives and pesticide systems.

New Reference Material

The case is already being made for greater emphasis on forest biotechnology. Some excellent references are appearing, both for the scientist and for the lay person who is an R&D manager responsible for providing guidance in science policy formulation and related budgeting.

One of the most recent is an article by Jakes and Risbrudt (1988), who argue that rates of return from forestry

research have been found comparable to those demonstrated in agriculture, which are "commonly in the range of 20 to 50%." Another assessment describes how the manipulation of biological processes "have the potential of doubling or even tripling the mean annual yields of our commercial timber stands ..." (Trotter 1986). Numerous citations are included to support his conclusions. This finding complements earlier work by Farnum, Timmis and Kulp (1983) who report that "Silvicultural and genetic manipulation of Douglas-fir and loblolly pine plantations have increased their productivity 70 and 300%, respectively, over natural forests on the same sites."

Still another source is the manuscript of a book that will soon be published on the benefits of forestry research (Hyde *et al.* 1989?). The draft of early chapters indicates that this will be a pioneering contribution on measuring research benefits. Finally, the Canadian Forestry Service is distributing a new study from Biotechnica Canada Inc., which provides further encouragement on the role of forest biotechnology in forest regeneration (DeYoe and Scowcroft 1988).

Evaluation Methods in Use

Before looking at the analytical options, it will be instructive to see how we are currently evaluating R&D opportunities. Forest scientists and economists are still deficient in their advice on biotechnology research agendas, in setting priorities and in estimating benefits. This situation is illustrated by four recent examples.

First, scan the Canadian Forestry Service (CFS) strategic plan for research (1987). Noticeably absent is a justification for the ranking of 11 topics on their list, nor does there seem to be supporting background material. The plan appears to throw the items up at random. No. 7 is tree improvement and genetics, while No. 11 identifies biotechnology as one of several special strategic concerns. The first item on the CFS list of research priorities is forest economics.

The second example of setting research agendas is one in which I participated in Toronto in January 1988. The Science Council of Canada was requested by the Natural Sciences and Engineering Research Council (NSERC) to recommend a set of priorities for strategic grants under each of four headings, one of them being biotechnology. A round table group of 15 members prepared an extended list of categories and then condensed it into a final set of 10 (Science Council of Canada 1988). At the top of the list we placed forestry biotechnology, specifically of conifers. Then came in order: human health care, animal productivity, cereals and oil seeds, environmental quality and so on.

There was no attempt to assess the relative costs and benefits. The exercise was rather a combination of intuition and considered judgment, reflecting both a sense for existing problems and the perceived likelihood of early results. Incidentally, this exercise came at the end of an extensive series of interviews within the science community across Canada, the results of which were consolidated in a set of working papers distributed before the round tables met. The example is cited here to indicate the relatively unsophisticated way we set priorities, but also to emphasize that a consensus did evolve rather quickly in favor of forestry biotechnology.

The third example was the Forest Sciences Forum convened in Edmonton in February 1988 by the Canadian Council of Forest Ministers. About 75 invited participants produced a list of 13 recommendations at the end of two days of

workshops and plenary sessions. Biotechnology appears in the forum proceedings as one of a subset under forest management. In this case there was no attempt to rank alternative forest science programs on a scale of urgency.

The fourth and final example of the present state of the art is taken from agricultural economics. Over the years numerous studies on a variety of topics have appeared that describe excellent annual rates of return. A 1988 report by McKenney, van Vuuren and Fox probed the economics of tree improvement. It was published, incidentally, by the Department of Agricultural Economics and Business at the University of Guelph. There is perhaps much to learn on evaluation methods from the agricultural economists.

Analytical Options

Recent research literature suggests that there are four main approaches to assessing the economic impact of biotechnology: (1) economic theory, (2) case studies of an *ex post* type, (3) *ex ante* evaluation, and (4) a consolidated overview. These are not strictly speaking discrete categories but it is useful for discussion purposes to regard them as distinct.

Economic Theory. Economists often use the concept of consumers' surplus, arguing accordingly that the supply curve shifts to the right as a result of research (Hyde *et al.*, 1989). Thus, more product is made available to consumers at the same or lower prices. For example, research on wood-based panels has consistently lowered costs and the resulting savings have generally been passed along to consumers. Producers' surplus results similarly as producers expand profit margins by a reduction in costs. Thus, improved seedling survival rates reduce the costs of forest renewal and contribute thereby to improved corporate financial performance.

Approaches along these lines may suggest some of the benefits to look for, although not necessarily all of them. It would be helpful to know how these benefits are distributed among producers and consumers, or between public and private sectors, and how to allocate the benefits among basic, applied and developmental phases of R&D (Hyde *et al.*). Nor is any light shed on the nature and extent of quality improvements as distinct from volume and price changes. It is clear that economic theory will not carry us very far in our search for estimates of the economic impact of research.

Ex Post Case Studies. A more popular choice is to resort to evaluations made after the research is completed. A favorite illustration from forest products R&D is the back pressure roller, a mechanical addition to the veneer lathe which is brought into position hydraulically opposite the peeling knife. It is reported to have resulted in a 17% volume increase in veneer recovery (Haygreen *et al.*, 1986). Similarly, a reduction by half in the time required to develop high quality conifer seed from special seed orchards means substantial savings. The same is true of greater seedling survival due to better nursery and planting technology. The benefit-cost ratios are easily demonstrated from such obvious success stories.

Ex post studies are often criticized because they tend to ignore the much longer list of unsuccessful projects that do not result in measurable cost savings or other benefits. This fault was recognized in a study of research benefits conducted for the US Forest Service by Haygreen and his colleagues. The team measured the impact of a number of their more successful timber utilization projects, concluding that the cumulative savings in raw material costs through to the

year 2000 of just seven of these paid for all of the utilization research conducted at Madison up to the present time. The annual rates of return on the selected projects ranged between 14 and 36%.

In short, while *ex post* cases taken by themselves may not satisfy all of the questions Treasury Boards or corporate finance committees are capable of raising about new projects, they do help to build a persuasive case for research in general.

Ex Ante Cases. A more important question at budget time is the extent to which we can build a convincing case for research before the fact. How can we assist the research team in presenting their case for a new project, to do so in an objective and responsible fashion?

The first point to recognize is that funding agencies and research managers reflect a broad range of policy targets. Within this range we find that economic efficiency criteria, in the classical sense, do not necessarily receive explicit consideration. Other criteria may be more helpful, such as the competitive balance in the market place for lumber. In such circumstances we can expect that fire retardance, or resistance to stain and decay, are likely to be given more consideration by funding sources. They also tend to favor basic research over applied. In addition, public agencies tend to emphasize export earnings, employment generation, environmental goals, grade standards, and other non-financial factors. This broad approach is certainly valid in an industry with annual sales of \$40 billion, nearly two-thirds of which are exported.

Experience has also shown that bureaucrats and their political masters can still be reached with a carefully framed argument based on projected financial benefits. For example, expenditures on forest renewal in Canada are now around \$1 billion annually. If we can raise the seedling survival rates by 10%, then a saving of nearly \$100 million is the approximate magnitude of the benefit. By way of a concrete illustration, Dr. Dennis Lavender of the UBC Forest Science Department has learned from his current research on seedling stress that cost savings of this magnitude may very well be realizable within as little as five years. It is reasonable in these circumstances to assume that one dollar in the laboratory and research plot will often return 10, 20 or more in operational cost savings.

Similar benefits may also be expected, in the medium and longer run, depending on the specific biotechnology program undertaken, as we measure improvements in the quality of fibre and reductions in rotation age from genetically improved plantations. An equally bold case can be made for intensive forestry treatments such as spacing and fertilizing. The traditional approach, which has been preferred by foresters since a celebrated article from German forestry over a century ago (Faustmann 1849), is to confine the measurement of benefits solely to incremental volume. This may at times give a convincing positive answer, but in the great majority of Canada's public forests it will not. Fortunately, we are not confined to the Faustmann arithmetic.

Consolidated Approach. The previous paragraphs suggest that there is a more forceful way in which to package the combined gains anticipated from forest biotechnology research. There are several benefits which are particularly appealing to the forest industry when consolidated in the following manner:

1. Volume increments
2. Cost reductions
3. Quality and value enhancement
4. Loss avoidance
5. Effluent cost control

While these benefits are now beginning to be calculated by forest land managers and producing companies, the relevant published literature is scattered and lacks synthesis (Reed 1988). Therefore a few comments on each of these points are included here.

First, the opportunities for producing more timber in our second growth plantations have already been noted. Doubling or even tripling the average yields of Mother Nature, left on her own, are regarded as technically feasible according to Trotter (1986). To be on the safe side, let's assume a conservative volume gain for managed stands. In addition to this, if we are able to grow the next crop more rapidly, then it follows that we can draw down the existing reservoir of old growth timber faster than we had planned initially. This is known in forestry circles as "the allowable cut effect". It means that we can cut more if we are growing more, assuming of course that we do have an adequate volume of old growth which is still available to industry and not tied up in reserves for wilderness or other single use categories.

In spite of evidence such as that cited above, many foresters still tend to speak of a limited annual payoff in the order of a 1-2% rate of return when dealing with volume increments. We must, however, check their assumptions closely, because they are usually talking about a single small stand that is planted today and matures in 80-100 years or more. Quite to the contrary, in Canada we are not starting from a single piece of bare ground, but with a large forest already in place. Much of this is mature old growth forest, and steadily increasing areas carry younger and middle-aged stands that will respond to silviculture treatments. Moreover, we have millions of hectares of productive forest land that will produce a valuable crop of fibre in 30-50 years if managed intensively. There is no justification for biasing the evaluation at the outset with excessive rotation ages and other conservative assumptions. We know that it is feasible to influence the stand dynamics of the existing forests with conventional silvicultural treatments and, using the newer tools of biotechnology, we are learning how to grow more rapidly a succeeding crop of better quality trees.

Second, traditionalists in forestry have been slow to include cost reductions in their list of benefits, even though considerable savings are anticipated. For example, it will cost less to harvest the fewer, more uniform and larger trees in a managed stand grown from superior seedlings. We can "bring the forest back to the mill" as it were, by concentrating intensive forestry within a 50-75-km radius of the plant facilities, thus reducing average hauling costs. It is also evident that processing the larger, more uniform and higher grade logs will be less costly for the sawmill that is utilizing trees from improved stands. The sum of these cost reductions will often exceed 25%. Some of the appropriate silvicultural treatments may have nothing to do with biotechnology, such as spacing. But they are still an important part of a systems approach to silviculture that will include biotechnology applications, both in the plantation phase and in subsequent protection from insects and disease. How long will it take to realize the benefits? Less than one might think, if you begin for example by fertilizing and spacing an immature stand. If the time remaining before harvest can thus be reduced from

say 25 to 15 years, then a shortage of mature timber and resulting curtailment in harvest can hopefully be offset in whole or in part.

Third, the enhancement of product value is an equally exciting prospect, due to a more attractive log mix. To begin with, we can influence the species composition in managed forests. Through genetic manipulation, we can also expect to increase tree size, fibre strength and log quality, using some of the techniques already applied in agriculture and horticulture. Gains can be expected from better tree form and structure, increased photosynthetic efficiency, and improved wood formation in the cell wall in a manner that will contribute to strength and specific gravity. These accomplishments will result in more profitable grades of lumber, higher lumber recovery per m³ of logs sawn, larger lumber sizes, and an increase in average sales realization well in excess of 25%. In addition, the quality and grade of residual chips sold to the pulp mills will be higher.

Fourth, we should be looking for loss avoidance. The most valuable timber we have is that which is already mature and scheduled for harvest within a decade. Losses from insects and disease have indeed been catastrophic in the last 40 years, often reaching 50% of the volume harvested. The development of insect pheromones holds genuine promise, while the value of treatments like Bt has already been demonstrated. The Canadian Forestry Service has spent around \$10 million on Bt research over the last 20 years. The timber already protected from insect damage by spraying with this virus is worth many times that research expenditure. Major benefits are also in prospect from cheaper herbicides for brushing and weeding in new stands. Once again, the benefits are likely to outweigh by far the associated research costs that we can visualize at the present time. Moreover, increasingly effective and economical forest protection may be the key to forestalling industry curtailments in communities where the mature timber supply is already dangerously low. The corresponding savings in social welfare budgets can be calculated easily and are a legitimate part of the benefit-cost calculation.

The fifth element in a consolidated approach is effluent cost. Reductions of processing costs in pulp and paper mills are more difficult to assess but the stakes are equally high. As much as a quarter or more of the cost of a kraft pulp mill is related to pollution control. Given the high capital and operating costs of treating effluent, an advance in anaerobic fermentation technology could easily be worth hundreds of millions in savings annually. There are other pressing environmental problems in lumber production, where fungal stain and decay could prove amenable to biotechnology research. This will reduce, and might eventually eliminate, the need for existing chemical treatments of lumber which have been under constant fire in recent years because of the associated health hazard.

Public Agency Concerns

Provincial forest ministries and federal agencies are just as interested in prudent use of research grant funds as companies are in bottom line profitability. As a general rule, however, public agencies place more weight on the following items, each of which will be positively affected by advances in biotechnology research.

1. Mitigation of environmental contamination
2. Economic development objectives

3. Social goals, such as employment and working conditions
4. Safeguards to human health

The distinction between public and private objectives is not absolute, but there is a generally accepted difference in emphasis.

Other measures are commonly employed in public discussions on the adequacy of research budgets. A favorite of the federal government and of those seeking to influence government research policies, is the ratio of research spending to GNP. Another is the practice of calculating ratios of the funds spent on research in an industrial sector to the selling value of that industry's shipments. These are compared in turn with ratios from other countries, an exercise in which Canada nearly always falls well below international averages and below our major competitors. These measures may indicate something about how serious we really are in maintaining a competitive stance internationally.

Recapping the Case for Biotechnology

How well do we use the pragmatic consolidated approach, or the other methods described above? With regard to influencing public or private research funding, our persuasiveness to date has been less than impressive.

The earlier text identifies a number of areas where biotechnology research holds the promise of important contributions to economic and social goals. This is most timely, because the Canadian forest sector is at a critical juncture relative to its ability to compete internationally. The costs of forest renewal alone are often in the range of 10-20% of the cost of delivering roundwood to our processing plants. Opportunities for reducing this cost cannot be ignored.

Quite apart from the enhanced economic viability of the industry, the entire community is counting on biotechnology for answers in the fields of environmental quality. The forest sector is under constant pressure to eliminate the use of chemicals in nurseries and for weed control in plantations, as well as for wood preservation and insect protection. Such important benefits of new technology directly involve the quality of life and the reduction of hazards to health. These cannot be translated easily into dollars and cents but are nonetheless among our top priorities.

In spite of the accumulating evidence on potential benefits, it is still fashionable in some circles to play down the opportunities offered by biotechnology research. The same people then complain that it is difficult to get consistent funding. My answer is this: Why should we fund the pessimist? Research managers have always been more responsive to the investigator who believes in a research proposal and is prepared to build an aggressive argument for support.

The optimists among Canada's forest scientists have put forward an aggressive research proposal on forest biotechnology, in response to the NSERC invitation under the Network Centres of Excellence program. Their agenda includes the following items:

1. Early genetic evaluation and selection
2. Sexual propagation, to ensure rapid turn around of generations
3. Asexual propagation for conifer improvement and clonal regeneration
4. Seedling propagation studies of physiological and biochemical mechanisms to reduce stress

5. Biofertilizer, including fungi to enhance mycorrhizal symbiosis of trees
6. Biocontrol of forest insect pests by improving Bt toxins
7. Biocontrol of fungal infections of trees, lumber and wood chips
8. Biological modifications of lignin and hemicellulose to enhance the bleaching process and strengthen the products
9. Molecular genetics and enzymology of wood modification

Yes, a growing number share the view that the door is now opening on a golden age in forestry science. The key to a successful entry as far as Canada is concerned is visionary leadership, of a style which recognizes that the timing is propitious and then seizes the evident opportunity.

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