NODA notes
NODA • EDNO
CANADA ONTARIO
Northern Ontario Development Agreement
Entente de développement du nord de l'Ontario
Forestry • Foresterie

NODA Note No. 33

ISSUES IN REALIZING ECONOMIC BENEFITS FROM RESEARCH: LESSONS FROM CASE STUDIES

Dan McKenney[1] and Kathy Campbell[1]

Glenn Fox[2], Naomi Beke[2], Gail Simkus[2]

INTRODUCTION

Economists are sometimes called upon to estimate the dollar benefits of research activities. For forest based research this is probably an impossible task, but it may be possible to identify a range of *potential* benefits. To think about the subject of economic benefits that arise from research it is necessary to have a framework to organize all the seemingly disparate data and information that is relevant to the problem. From an economic perspective, research is for the purpose of generating new knowledge or technology that could have an impact on production, likely causing a decrease in supply costs (see Fig. 1). Extending this concept across regions and outputs or commodities that are the target of research programs can be done by applying multi-region, multi-commodity trade models that include forestry products (see Davis et al. 1994a,b; McKenney et al. 1994).

Three aspects of the potential impact of research are illustrated in Figure 1. The "before research"commodity supply is represented as S_0. If research is undertaken, is successful, is applicable, and is adopted by all producers of the commodity, then the supply is expected to shift to S_1^*. The vertical shift in this supply represents the potential unit cost saving owing to research, k. In this situation the annual welfare gains from research are measured as the area, *txwv*. Since research is a risky activity and research institutions have differing strengths in undertaking different types of research, the potential cost reducing effects of the research may not always be realized. The expected shift in the supply may, therefore, be less than ideally thought, e.g., to S_1' instead of S_1^*. In addition, because all producers may not adopt the new technology generated by the research, the impact of the research as measured here in terms of all industry production needs to be adjusted by the adoption levels. Therefore, in any year the expected shift in the supply would only be from S_0 to S_1. The expected cost reduction is k and the expected annual welfare gains from the research are measured as the shaded area, *txyr*.

A novel aspect of this work when applied across regions is that it explicitly tries to deal with the notion that research in one ecological zone may have relevance to other areas. This notion of spillovers is an important economic rationale for publicly funded research. A schematic of the general modelling framework is shown in Figure 2. The principles apply equally to priced or unpriced values.

Consider a situation where research occurs in one region and is targeted at one particular commodity. It is assumed that projects are designed to develop new knowledge and/or technology that could be used by scientists, foresters, planners, etc. There is of course the risk that the project will not generate any new knowledge, ideas or technologies even after a significant period of time. The reasons for this can range from the capacity of the researcher(s); the research support, and of course the nature of the problem under investigation. Whatever the reasons, the economic impact of the research would cease at this point.

If the research is successful, the output is generally some new knowledge or technology that could potentially be

[1] Landscape Analysis and Applications Section, Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, Ontario

[2] University of Guelph, Guelph, Ontario

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts

Ontario
Ministry of Natural Resources / Ministère des Richesses naturelles

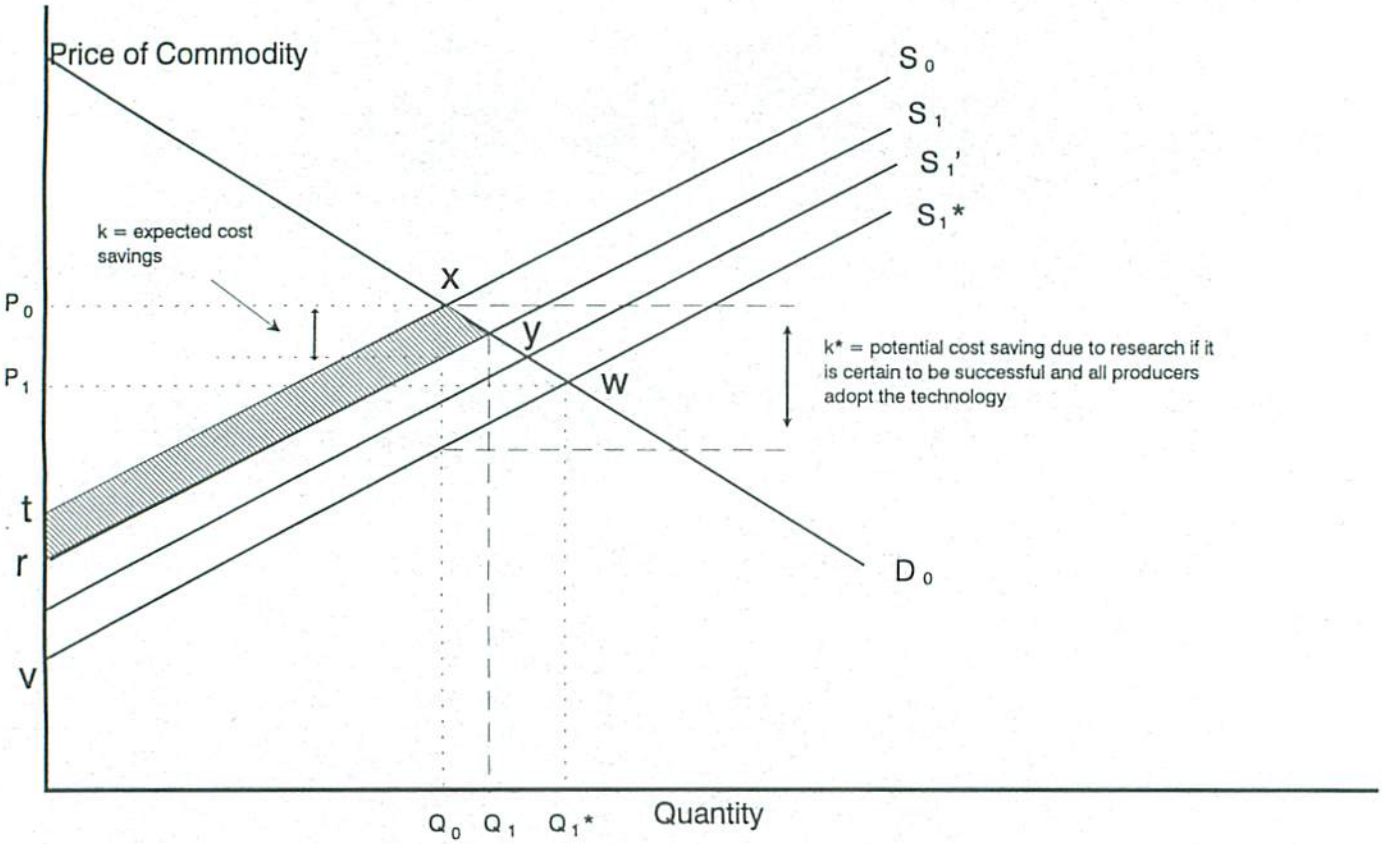

Figure 1. Measuring the annual economic surplus generated by research with adoption and the chance of research success

used or *adopted*. Research success does not guarantee adoption. Results may be redundant or more costly than current practices and decision-makers may be reluctant to change or require additional education. Thus the impact of even successful research can be diluted by non-adoption. This is the area where technology transfer practitioners can influence the realization of research benefits.

Once developed and adopted, knowledge or technology could influence production from individual forests or ultimately the entire region. This eventually changes output levels or the value of output of the commodity, and, depending on the market conditions, consumption levels within the region. At this stage the demand and supply conditions for the commodity become an important component of the research process. Changes in these conditions can affect the welfare of different groups. In Figure 2 these are *consumers* and *producers*; however, in principle a range of disaggregations can be considered (e.g., particular producers). Changes in welfare to producers and consumers can be influenced by several factors. Research may create some *externalities* in the region (i.e., create some costs and/or benefits other than those directly reflected in the forest production and cost conditions). The effect of chemical pesticides on water quality or decreased soil erosion through alternative management practices are two forestry examples.

Another factor that can influence welfare changes is existing government policies. Examples include taxes, regulations and other incentives or disincentives that influence production or consumption decisions. Many of these can be classified under the general heading of "property rights". A clear understanding of these will help technology transfer practitioners deal with impediments to adoption. Government policies can affect both the magnitude of welfare changes from research and the distribution of the gains (or losses).

A factor not clearly indicated in Figure 2 is the *time lag* between research and eventual changes in production. Lags arise for numerous reasons and affect the net value of the welfare changes through time. The dictum of "A dollar today is preferred to a dollar tomorrow" applies equally to research. From the perspective of economics, all basic and applied research is an *investment* expected to yield some future gains. Quantifying potential returns from basic research is particularly challenging.

Multiple Region Multiple Commodity Example

To this point we have been describing the research process for a single commodity in a single region. Such regions are usually geo-politically defined (e.g., Ontario or British Columbia). To be more relevant, it is better to consider the region as an area or set of relatively homogeneous ecological conditions. These can be termed *production environments*. In most countries forests extend over many geo-political boundaries and ecological regions or production environments. This recognition adds a number of dimensions to the research process. Even though

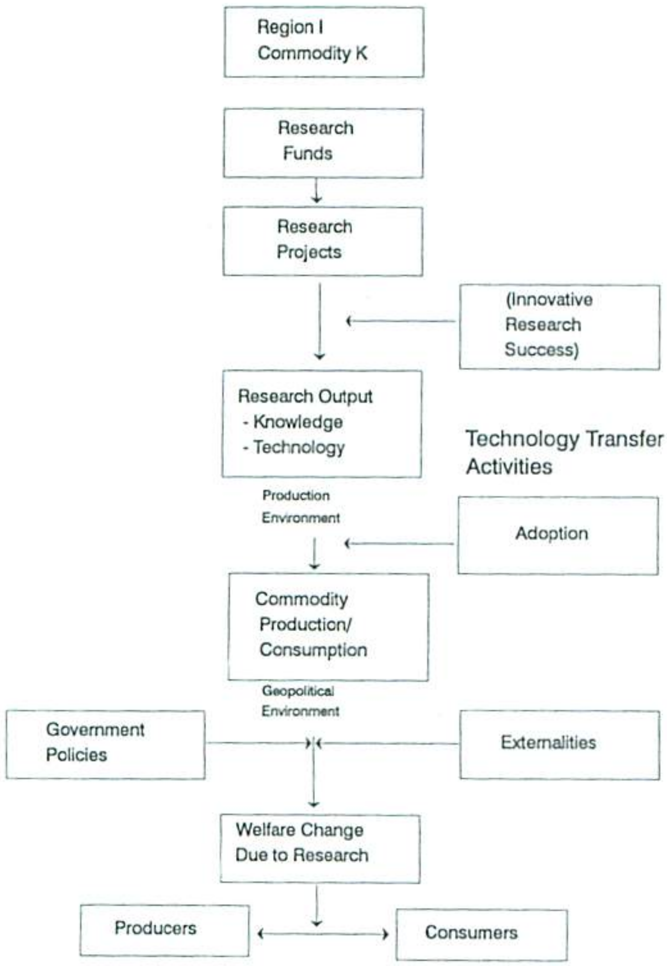

Figure 2. Single commodity single region research process

research may originate in one region, the knowledge or technology may be applicable to other regions i.e., *research spillovers.* If the other regions have different production environments, then *adaptive research* may be necessary to make the results relevant. Depending on the strength or capacity of the other research systems, the adaptive research may or may not be successful. Thus research spillovers may or may not eventuate.

Again if research results are adopted in other regions, production will be affected. Depending on the market conditions and the impact of the research, the price of the commodity may change *(i.e., price spillovers)* again. Externalities and government policies can also have an impact on the other regions. All of these interactions can lead to changes in welfare. Lag times are also an important component of this entire process.

The addition of research on other commodities increases the dimension of the process. Similar interactions can occur and although more complex, research spillovers may occur between commodities.

The Australian Centre for International Agricultural Research has an information system based on the above framework. The system is used to generate information on potential benefits of research on a wide range of agricultural, fisheries and forestry commodities. The impact of technology transfer mechanisms is implicit in the assumptions about adoption levels. Development of the system was deemed useful for several reasons:

- increased requirements for public sector accountability;
- the diverse nature of mandated research areas and the need to make useful comparisons between these;
- given the expectation that scientific expertise within organizations changes through time, institutionalizing a system captures the knowledge gained through this evolution.

The model makes use of the extensive research evaluation literature that has been developed over the last two to three decades, particularly in agricultural economics (e.g., see Norton and Davis 1981, Alston et al. 1995). The modelling component of the system is a *multi-region* trade model and uses the economic concepts of consumer and producer surplus to estimate the potential welfare effects of research as described above. A range of economic data (actual or estimates) are required to model these possible effects: defining a product or output (e.g., rice or coniferous sawlogs), historical production and consumption levels, prices and elasticities (the sensitivity of production and consumption to changes in prices). An important starting point assumption in the following applications is that research results in a standard 5 percent reduction in the cost of producing a unit of the commodity. If these *unit cost reductions* are known or estimated separately, prices are not required. The link between unit cost reductions and forest utilization type research is intuitively obvious in work like what is done by the Forest Engineering Research Institute of Canada, FERIC. This link is less clear but nevertheless germane to forest-based research (e.g., physiology, silviculture, entomology, genetics research, etc.). In these cases the lags may be different and/or the research may be relevant to a range of species and commodities.

Table 1 provides gross estimates of research benefits in a Canadian context. The potential national benefits from research are calculated over a 30 year time horizon using an 8 percent real discount rate. Interpreting the results requires careful consideration of the underlying assumptions (e.g., lags, spillovers, etc.) (See McKenney et al. 1994 for details). However at this macro level the values for Ontario research are over $400 000 000, suggesting an important rationale for both research and technology transfer activities. The eight forestry products in the table were based on the United Nations Food and Agriculture delineation of forest products. They were chosen to reflect forest-based research and avoid double counting and over-estimating benefits. Over-estimation might occur if the value of production and consumption of products further down the processing chain were used as the basis of the unit cost reductions. In other words the value of forest

Table 1. National benefits by province ($ million)

Newfoundland

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	108
Pulpwood	17
Fuelwood coniferous	3
Saw & Veneer Logs N	2
Fuelwood NC	2
Other Ind. Roundwood	0
Total	132

Prince Edward Island

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	107
Pulpwood	12
Fuelwood coniferous	2
Saw & Veneer Logs N	2
Fuelwood NC	2
Other Ind. Roundwood	0
Total	125

Nova Scotia

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	112
Pulpwood	18
Fuelwood coniferous	3
Saw & Veneer Logs N	2
Fuelwood NC	2
Other Ind. Roundwood	0
Total	137

New Brunswick

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	244
Pulpwood	90
Fuelwood coniferous	8
Saw & Veneer Logs N	6
Fuelwood NC	3
Other Ind. Roundwood	3
Total	354

Quebec

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	316
Pulpwood	82
Fuelwood coniferous	40
Saw & Veneer Logs N	17
Fuelwood NC	5
Other Ind. Roundwood	3
Total	463

Ontario

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	253
Pulpwood	90
Fuelwood coniferous	47
Saw & Veneer Logs N	16
Fuelwood NC	3
Other Ind. Roundwood	3
Total	412

Manitoba

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	208
Pulpwood	43
Fuelwood coniferous	21
Saw & Veneer Logs N	10
Fuelwood NC	2
Other Ind. Roundwood	2
Total	286

Saskatchewan

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	141
Pulpwood	28
Fuelwood coniferous	12
Saw & Veneer Logs N	4
Fuelwood NC	2
Other Ind. Roundwood	1
Total	188

Alberta

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	169
Pulpwood	28
Fuelwood coniferous	12
Saw & Veneer Logs N	3
Fuelwood NC	1
Other Ind. Roundwood	1
Total	214

British Columbia

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	291
Pulpwood	
Fuelwood coniferous	3
Saw & Veneer Logs N	1
Fuelwood NC	1
Other Ind. Roundwood	0
Total	296

Yukon/Northwest Territories

Commodity Ranking	Regional Benefits
Saw & Veneer logs C	148
Pulpwood	4
Fuelwood coniferous	1
Saw & Veneer Logs N	1
Fuelwood NC	0
Other Ind. Roundwood	0
Total	154

C - Coniferous
N - nonconiferous

research should not be based on price of newsprint but rather the value of standing timber. This is the case if the purpose of the research is primarily targeted at wood production from forests.

The results presented here assume the same adoption levels for all products. Technology transfer mechanisms may be more effective for different products (issues) and across regions. Research opportunities also vary regionally and are influenced by the strengths of research institutions. To make this analysis more relevant at a regional scale, production environment/ecoregions should be redefined (e.g., an Ontario Ecological Land Classification), the analysis could focus on species rather than commodities and, non-wood values and their relative importance in forest research need to be explicitly addressed in a systematic manner.

PROJECT LEVEL ASSESSMENTS OF FOREST RESEARCH AND DEVELOPMENT

Detailed project level assessments may also be of interest to technology transfer practitioners and research planners since they provide more details on the costs of adoption and lag periods. At the project level, a range of research evaluation frameworks have been used to assess the impact of research. Some are very simple and estimate the value of the research as the expected increase in production at the current or expected price. Others are more complex, such as those described in the previous section.

Evaluation approaches that are less sensitive to demand and supply conditions are generally preferred. The assessments below attempt to follow this strategy and are based on Figure 3 from McKenney et al. (1993). The basic approach is attempting to quantify how much production costs will/could change due to the research. Net gains can then be calculated inclusive of research costs.

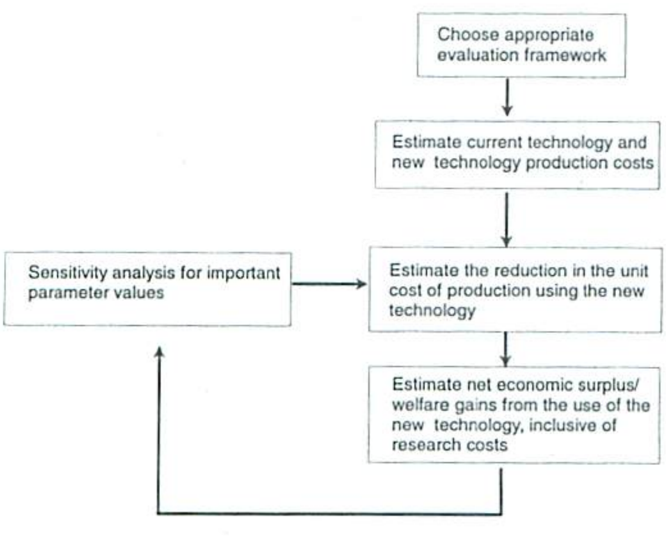

Figure 3. Steps in evaluating the impact of research

A Tree Improvement Case Study

(from McKenney et al. 1989, 1992)

For the purposes of economic evaluation, tree improvement should be divided into a research and development component and an operational component. Figure 4 illustrates this delineation. In the research phase, superior-looking trees called plus-trees are selected in the forest, and test plantations are established to identify which parent trees will produce the most genetic gain. These test plantations, called progeny and/or family tests, evaluate genetic characteristics of the plus-trees, which are used as parents for improved plantations. Characteristics such as height growth, diameter growth, form, and sometimes various wood-quality attributes are measured. Since genetic gains are permanent increases in productivity, the cost of this research should be applied to the entire land-base over which the improved trees are planted for all current and future plantations. The potential land-base for improved planting stock may be restricted for either ecological or administrative reasons. It is common practice not to move stock too far from its place of origin to reduce ecological risks.

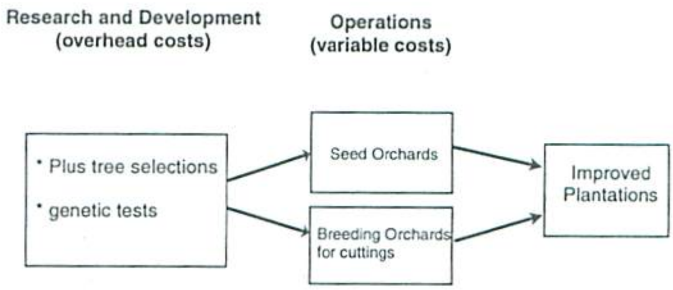

Figure 4. Tree improvement in forest management

The operational aspect of tree improvement is simply the mass production of genetically improved stock for plantations e.g., seed orchards to produce improved seed or breeding orchards to produce clones for rooted cuttings.

Seed production in seed orchards fluctuates over time. However, seed orchards are established as a means of obtaining improved seeds over an extended period of time, so some mechanism is needed to allocate annual costs over the lifespan of the orchard. The average annual operational cost of a seed orchard can be computed by compounding all annual orchard costs forward to the end of the seed orchard's life. This compounded value of annual orchard costs is converted into an annuity (equivalent annual cost) over the seed orchard's productive life. To convert this annuity into an average operational cost per hectare of improved plantation, the annuity is divided by the average annual number of hectares established. In the examples used here it was assumed that the orchards have a 40-year lifespan. Table 2 summarizes some operational orchard costs, ranging from $17–109 for black spruce (*Picea* *mariana* [Mill.]B.S.P.) to $16–98 for jack pine (*Pinus banksiana* Lamb.). The range is presented to highlight the point that some regions may not have a land base to support large annual planting programs.

In the rooted cutting (clonal) approach, a breeding orchard has a dual purpose. Most importantly, it provides the source of test material by which gains can be made. It is also the initial parental source for cuttings to be used in plantations. As emphasized earlier, it is essential to make a distinction between R&D and operational costs in analyzing the economics of tree improvement. We have assumed that all establishment costs for a breeding orchard should be treated as R&D costs. The only operational costs for a breeding orchard are maintenance costs such as insect and disease control, moving, and some controlled pollination to replace nonvigorous aging parent trees in the cutting multiplication process. The 1989 study assumed annual operating costs to be approximately $500 per year for maintenance and $1 500 per year for controlled pollination for clonal planting programs of 500 ha or less. For annual planting programs of greater than 500 ha, the assumption was that controlled pollination costs increase but that the unit costs remain the same. Table 3 also summarizes the operational costs of clonal forestry tree improvement per hectare of improved plantation. These costs are small relative to all other reforestation costs and in fact represent one of the major advantages of clonal forestry.

Table 2. Additional establishment costs per hectare of improved plantation.

Maximum annual planting rate[1] (ha)	Black spruce[2] Orchard ($)	Black spruce[3] Cuttings ($)	Jack pine[4] Orchard ($)
200	109	10	98
400	54	5	49
500	45	4	39
1 000	25	4	16
1 500	19	4	16
2 000	17	4	not applicable

[1] The greatest annual potential planting rate assumed to be 2 000 ha for black spruce, 1 500 ha for jack pine due to seed production levels.

[2] Based on an annuity of $21 708 (4 percent discount rate) over 33 years of productive orchard life.

[3] Based on annual costs of $500 for maintenance of a breeding orchard and $1 500 for controlled pollination for planting program of less than 500 hectares. For planting programs greater than 500 hectares, total costs increase but unit costs remain constant at $4.00 per hectare of improved plantation. Figures in the table were obtained through discussions with OMNR staff. Stock production costs are included in the plantation establishment and management costs.

[4] Based on an annuity of $19 514 (4 percent discount rate) over 35 years of productive orchard life. Jack pine produces more seed and at an earlier age than black spruce.

Table 3. Representative establishment costs of plantations using improved and unimproved stock. ($/ha)[a]

Activity	Unimproved	Black spruce orchard	Jack pine orchard	Black spruce clones
Operational tree improvement	0	17–109	16–98	4–20
Seed collection[b]	7	7	7	0
Stock production[c] @2 000 trees/ha	339	339	339	450–1 200

[a] All costs are in 1983 dollars (converted with the consumer price index) (based on McKenney et al. 1989, 1992)

[b] Tree Seed and Forest Genetics Unit. Although seed orchard seed collections were assumed equal to general collections; recent experience suggests orchard collections are more expensive (D. Joyce Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Pers. Comm.). A more recent study indicates that costs now range from $6.80-$8.60 for black spruce and jack pine general collections (1992 dollars, Sarker, McKenney, Joyce, 1995).

[c] OMNR sample price from private container stock grower. Recent cost estimates range from $500-$900/2000 seedlings depending on the age of the stock.(J.McCaugherty, OMNR, Sault Ste. Marie, ON. Pers. Comm.)

Stock production costs are not included in operational costs, but are included directly in establishment costs of improved plantations. Cutting production for improved plantations is much more expensive than conventional stock costs used for both the seed orchard and unimproved approaches. Cuttings can be produced for plantations either through serial propagation techniques or hedge orchards. It is not limited by seed production as in the seed orchard.

In 1986, the Ontario Ministry of Natural Resources (OMNR) was purchasing cuttings from a private facility for over $600 per thousand. At the time of the study some OMNR nursery personnel thought that cuttings could be produced in the range of $325 to $350 per thousand. For the study, two costs for cutting production were used - $325 and $225 per thousand. The lower cost was intended to represent possible future cost savings as knowledge of rooted cutting production advances (e.g., production through hedge orchards). In fact, Ontario's black spruce clonal forestry program appears to be on hold at the moment due to fiscal constraints. Production costs do not appear to have been reduced much since the initial study (R. Ford, pers. comm.)

In intensively managed plantations, which use genetically improved stock, establishment costs include seed collection, stock production, site preparation, and planting. The operational costs of tree improvement are treated as an establishment cost. Table 3 identifies costs associated with the three tree improvement approaches and the option of unimproved planting stock. Establishment and management activities can be assumed identical for improved and unimproved plantations. However the costs of these activities differ.

Ultimately, the impact of tree improvement research is reflected as a change in the biological growth function. However, it is the change in the value of the growth function that is relevant for economic analysis of technical change in forestry (Johansson and Lofgren 1985). Information on costs, stumpage values and growth rates are required.

Given the range of costs, expected changes in growth rates and a wide range of stumpage values the results from McKenney et al. (1989 and 1992) suggested that:

- tree improvement is best practiced on the most productive land and can generate significant benefits but it depends on how it is implemented;
- jack pine seed orchard tree improvement was generally more worthwhile than black spruce seed orchards;
- clonal forestry was too expensive even at $225/1 000 cuttings to be economically worthwhile even though significantly higher genetic gains are possible.

The factors that influenced these results included potential size of the improved planting program, magnitude of the potential gains in yield, orchard fecundity and relative costs to achieve the gains. These are examples of factors that should be considered in setting research and development priorities and issues researchers could contemplate when considering options in their own research portfolios.

Application of Portable GPS/Desktop-GIS For Forest Fire Management Support

(from Fox et al. 1996[3])

NODA/NFP Project (No. 4201) investigated the feasibility of implementing a user friendly, portable, low-cost technology using a Global Positioning Satellite System (GPS) and a notebook-based Geographic Information System (desktop-GIS) (Tortosa[4]) to support forest fire control and management.

Prior to the introduction of the GPS/GIS technology, fire boundaries were hand-sketched while flying the perimeter of the fire. GPS/GIS technology offers a new method of determining fire boundaries. With this system, while a helicopter flies the perimeter of the fire an on-board GPS receiver calculates and stores the positions of the aircraft. The GPS coordinates defining the fire boundary are then transferred to a GIS and a map of the fire is produced.

Through this technology, information can be relayed to the fire fighting crews, providing them with more accurate maps more quickly than previously possible. The new system can assist fire bosses to: manage fire fighting resources more efficiently, produce fire suppression lines, and determine other values at risk (e.g., homes, lodges, etc.)

The NODA (Northern Ontario Development Agreement) project and some prior investigations of the technology identified some direct cost savings. For example, in one fire, maps were drawn by hand and by using the GPS/GIS. The hand drawn map took 1.5 hours to complete, whereas the GPS/GIS map was completed in 30 minutes. When the GPS/GIS system is used, fewer people are required for map production allowing individuals to be allocated to other fire fighting roles or resulting in a reduction of fire fighting staff. If a map is required in a hurry, a notebook computer with the GPS/GIS software could be taken in a helicopter.

---

[3] Fox, G.; Beke, N.; McKenney, D.; Simkus, G. 1996. Economic evaluation of forest research: Three case studies. Nat. Resour. Can., Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON. NODA/NFP File Report.

[4] Tortosa, D. Project Proposal for NODA/NFP Project No. 4201: Application of a portable GPS/desktop mapping system for fire management support.

Costs and benefits were estimated for each year over a ten year period. Costs of adoption included: costs of purchasing required equipment, maintenance costs, training costs and NODA project costs. For the analysis, costs were subtracted from the savings in decreased flying time (yielding net benefits). Net benefits were then discounted to present value terms and summed to determine the net present value.

Many of the numerical values used in research evaluations are not known with certainty, particularly future values. The software @Risk was used to deal with this uncertainty. @Risk permits users to perform hundreds of 'what if' scenarios (sensitivity analysis) by permitting the numerical estimates of model values to vary within a defined probability distribution. The results provide the range of net present values likely, given assumptions about the important model parameters. In this study, helicopter costs, fires per year, hours saved, and training and maintenance costs, were all uncertain. Each of these variables was assumed to be normally distributed with a mean value equal to the initial assumptions. A standard deviation was also assigned to each variable according to the degree of uncertainty associated with it. The more uncertain the initial value, the greater the standard deviation and vice versa. Fires per year and hours saved were considered more uncertain than helicopter costs and training and maintenance costs. The number of fires in a given year are random acts of nature. Hours saved depend on the number of maps required for a given fire. This could vary from one fire to the next depending on the severity of the fire. Severity relates to the size of the fire as well as the rate of spread of the fire. These variables help to determine the number of maps required for each fire. The more uncertain variables were assigned a standard deviation of 30 percent of the mean (or expected value), as opposed to 20 percent for the less uncertain variables. Using this method yields a range of the likely present values of research benefits that is normally distributed with a mean value and standard deviation. Table 4 presents some results.

In this analysis the range of present values was from about \$300 000–10 000 000, and the probability of a positive result was 100 percent indicating this project has a high likelihood of a positive payback. Technology transfer activities were/are not really required given the OMNR's positive experience with the approach. However opportunities may exist outside the province. As a final note, this project would not likely be classified as research but rather as a feasibility study for adopting a particular technology.

UNEVENAGED SILVICULTURE FOR PEATLAND SECOND-GROWTH BLACK SPRUCE

(from McKenney et al. 1997)

NODA/NFP project 4042 was a joint investigation undertaken by the Canadian Forest Service (CFS), Abitibi-Price Inc., and the Forest Engineering Research Institute of Canada (FERIC). The objective of the research was to provide information on aspects of unevenaged silviculture for second-growth black spruce swamps, including: (1) harvesting costs, productivity and equipment suitability (2) damage to residuals and advance growth (3) forecasts of stand structure and growth (4) analysis of wood supply implications and (5) the transfer of technology relating to harvesting equipment and techniques required to implement unevenaged silviculture.

Stand growth forecasts were to be developed for second-growth peatland black spruce using a partial cutting technique for harvest. It was hypothesized that this harvesting technique would yield an increase in merchantable volume for the second-growth, from 1.3 to 2.0 m^3/ha/year, to 2.4 to 3.6 m^3/ha/year (see also Groot and Horton 1994).

Productivity and cost effectiveness of the new partial cut harvesting method is being tested in various stand conditions using two types of equipment, however, it is also yet to be determined if the standard equipment is adequate for this type of silviculture.

Table 4. Expected present value (4 percent discount rate) benefits from the NODA GPS/GIS project

Variable Considered Uncertain (mean, Standard deviation)	Expected Mean(\$)	Maximum Result (\$)	Minimum Result (\$)	Standard Deviation (\$)	Probability of Positive Results (percent) Results
All Variables Considered Uncertain	3 485 882	9 871 688	286 517	1 432 635	100

Uncertain Variables: All variables that were individually considered uncertain, were combined in this simulation. Each variable is assigned a mean value and standard deviation denoted as (mean, standard deviation) following the variable name:

Helicopter Costs (\$/hour): (900,180)
Fires/year: Project (8,2.4), Northern (400,120), Small (100,30)
Hours Saved: Project (5,1.5), Northern (1,0.3), Small (1,0.3)
Training Costs (\$/5 years): (5 000,1 000)
Maintenance Costs (\$/year): (2 000,400)

Evaluating the potential benefits of this research project involved a number of steps that exemplify the challenges of economic evaluations of forestry research i.e., estimating growth responses, forecasting future stumpage values, identifying likely harvest cost differences between prescriptions. Two types of harvest were investigated: a method of clearcutting presently employed by Abitibi Price and a partial cutting method. The current clearcut method generally removes all trees with a diameter at breast height (DBH) of 10 cm and greater. However, not as much care is taken with the smaller trees and only enough trees are left to meet the minimum stocking condition that the OMNR requires. The partial cutting method was divided into three harvest classes: (1) all trees 10 cm DBH and higher are removed (a complete harvest), (2) all trees 15 cm DBH and higher are removed (a medium harvest), and (3) all trees 18 cm DBH and higher are removed (a light harvest). In the case of the partial harvest, care is taken not to damage the remaining smaller trees. For the economic analysis it was assumed that subsequent harvests would occur at 25 year intervals.

An important determinant of the value of the adoption is the relative harvesting costs of each method. In a recent report, Gingras (1994) estimated that partial harvest costs are \$12.35/m^3 of merchantable volume, compared to \$13.06/m^3 of merchantable volume for the clearcut method. Abitibi Price does not agree with these figures, and feels that their current harvest method (clearcut) is less costly. Since the true harvest costs are unknown, various costs simulations were used.

The cost difference between the existing harvest method and the selective cutting methods is the sacrifice of adopting the new technology. In the case of the light harvest, the per m^3 cost of adoption is \$0.50 and similarly, \$1.00 and \$1.50 for the medium and complete methods, respectively. The benefits are changes in the potential flow of wood from the stand through time. Table 5 summarizes an @Risk analysis of this project using a 4 percent discount rate. The major assumptions are listed in the table. The results range from a whopping negative \$235 000 000 to over \$170 000 000. Probabilities of a positive result range from 3–66 percent depending on the harvest method.

Clearly implementing this partial cutting system may not yield benefits to wood producers. Much depends on what you believe the future value of standing timber to be relative to today. However, unpriced benefits (e.g., aesthetic qualities of this harvest method and a better habitat for certain types of wildlife) may be enough to compensate for the cost difference between the new and old harvest methods. Using the most negative value as the base and an Ontario population of 10 084 885 this works out to \$23.30/person or \$ .93/person/year. The latter number is what people would have to be willing-to-pay to justify implementing the light harvest method on economic efficiency grounds. Whether this is a big or small number depends on your perspective. Also one should consider whether research or silvicultural treatments such as these are the most cost effective way of achieving non-wood objectives.

Table 5. Potential benefits from uneven-aged silviculture NODA project inclusive of research costs

Statistic	Light Harvest	Medium Harvest	Complete Harvest
Expected Mean	- \$72 552 260	- \$1 010 054	\$20 819 790
Maximum Result	\$30 256 580	\$115 228 200	\$170 352 700
Minimum Result	- \$235 417 500	- \$188 086 300	- \$135 478 300
Probability of a Positive Result	3 percent	53 percent	66 percent
Standard Deviation	\$44 976 720	\$47 831 170	\$49 471 180

Uncertain Variables:

All variables that were individually considered uncertain, were combined in this simulation. Each variable is assigned a mean value and standard deviation denoted as (mean, standard deviation) following the variable name:

- Harvest Yields (cubic meters/ha):
  - Clearcut - initial (124,24.8); Clearcut - subsequent (62, 18.6)
  - Light - initial (44, 8.8); Light - subsequent (21, 6.3)
  - Medium - initial (86, 17.2); Medium - subsequent (32, 9.6)
  - Complete - initial (124, 24.8); Complete - subsequent (24, 7.2)
- Difference between clearcut and partial harvest costs (\$/cubic meter):
  - Light (0.50, 0.10)
  - Medium (1.00, 0.20)
  - Complete (1.50, 0.30)
- Stumpage values (\$/cubic meter):
  - Present (10, 2)
  - Future (25, 7.5)

CONCLUDING COMMENTS

Quantifying the net economic benefits from research is a difficult task. For most research and development, technology transfer activities are explicitly required to realize benefits. Even if research is successful there can be many impediments to adoption and the realization of benefits, not the least of which is dealing with the volumes of information being produced by researchers worldwide. Costs and benefits will be distributed unequally amongst potential users. Research planners and technology transfer practitioners should be explicitly aware of these types of potential conflicts. Such clarity would help focus research and technology transfer efforts. It would also force explicit consideration of issues such as research and adoption lag periods, potential adoption levels, potential for spillovers, relative values and production and consumption levels, key issues in realizing economic benefits from research.

LITERATURE CITED

Alston, J.; Norton, G.; Pardey, P. 1995. Science under scarcity. Cornell University Press, Ithica, NY.

Davis, J.S.; Bantilan, M.C.; Ryan, J.G. 1994a. Development of information system to support research decision-making: An overall perspective. Chapter 2 *in* J.S. Davis and J.G. Ryan, Designing information systems to support priority assessments in agricultural research: Concepts and practices for international and national institutions. Aust. Cent. Int. Agric. Res. Canberra, Australia, Monagr. 17.

Davis, J.S.; McKenney, D.W.; Turnbull, J.W. 1994b. The international impact of forestry research and a comparison with agricultural and fisheries research. Can. J. For. Res. 24:321–336.

Gingras, J.F. 1994. A comparison of full-tree versus cut-to-length systems in the Manitoba Model Forest. Forest Engineering Research Institute of Canada, Pointe-Claire, PQ. Special Report SR-92.

Groot, A.; Horton, B.J. 1994. Age and size structure of a natural and second growth peatland *Picea mariana* stands. Can. J. For. Res. 24:225–233.

Johansson, P.O.; Lofgren, K., 1985 The economics of forestry and natural resources. Basil Blackwell, Oxford, pp; 100-107.

McKenney, D.W.; van Vuuren, W.; Fox, G.C. 1989. An economic comparison of alternative tree improvement strategies: Simulation approach. Can J. Agric. Econ. 37:221–232.

McKenney, D.W.; Fox, G.; van Vuuren, W. 1992. An economic comparison of black spruce and jack pine tree improvement. Forest Ecology and Management 50:85–101.

McKenney, D.W.; Davis, J.S.; Turnbull, J.W.; Searle, S.D. 1993. Impact of Australian tree species selection research in China: an economic perspective. Forest Ecology and Management 60:59–76.

McKenney, D.W.; Davis, J.; Campbell, K.L. 1994. Towards an information system to support forestry research priority setting: Some preliminary results for Canada. Nat. Resour. Can.,Canadian Forest Service–Sault Ste. Marie, Sault Ste. Marie, ON. Inf. Rep. O-X-433. 19p. + appendix.

McKenney, D.W.; Beke, N.; Fox, G.; Groot, A. 1997. Does it pay to do silvicultural research on a slow growing species? Forest Ecology and Management. 95 (2): 141–152 .

Norton, G.W.; Davis, J.S. 1981. Evaluating returns to agricultural research: A review. Am. J. Agric. Econ. 63:685–699.

Sarker, R.; McKenney, D.W.; Joyce, D. 1995. SEEDCOST: The cost of seed for artificial regeneration in Ontario. Ontario Ministry of Natural Resources, Sault Ste. Marie, ON. Genetic Resource Management General Tech. Rep. No. 2.

The views, conclusions, and recommendations contained herein are those of the authors and should be construed neither as policy nor endorsement by Natural Resources Canada or the Ontario Ministry of Natural Resources. This report was produced in fulfillment of the requirements for NODA/NFP Project No. 4306, "Economic evaluation of forest research: A framework for allocation of research funds".

Additional copies of this publication are available from:

Natural Resources Canada
Canadian Forest Service
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7
(705)949-9461
(705)759-5700(FAX)

Catalogue No. Fo 46-14/1-1998E
ISBN 0-662-26452-5
ISSN 1198-2233

This report is printed on recycled paper.