TOWARDS AN INFORMATION SYSTEM TO SUPPORT FORESTRY RESEARCH PRIORITY SETTING: SOME PRELIMINARY RESULTS FOR CANADA

D.W. McKenney, J.S. Davis[1], and K.L. Campbell

Natural Resources Canada
Canadian Forest Service – Ontario
Great Lakes Forestry Centre

1994

Information Report O–X–433

1 Australian Centre for International Agricultural Research

Canadian Cataloguing in Publication Data
D.W. McKenney
Towards an information system to support forestry research priority setting : some preliminary results for Canada
(Information report ; ISSN 0832–7122 ; O–X–433)
Includes an abstract in French.
Includes bibliographical references.
ISBN 0–662–21542–7 Cat. no. Fo46–14/433E

1. Forests and forestry – Research – Canada.
2. Forests and forestry – Research – Economic aspects – Canada.
I. J.S. Davis II. K.L. Campbell.
III. Great Lakes Forestry Centre. IV. Title.
V. Series: Information report (Great Lakes Forestry Centre); O–X–433.
SD356.54C3M34 1994 634.9.0971 C94–980140–2

Catalogue No. Fo 46–14/433E
ISBN 0–662–21542–7
ISSN 0832–7122

Copies of this publication are available at no charge from:
Communications Services
Natural Resources Canada
Canadian Forest Service – Ontario
Great Lakes Forestry Centre
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

Microfiches of this publication may be purchased from:
Micro Media Inc.
Place du Portage
165, Hotel-de-Ville
Hull, Quebec J8X 3X2

McKenney, D.W.; Davis, J.S.; 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 – Ontario, Sault Ste. Marie, Ont. Inf. Rep. O–X–433. 19 p. + appendix.

ABSTRACT

A framework for generating quantitative economic information about potential research benefits is described. The approach has been used in an international context to support agricultural, fisheries, and forestry research priority setting. This report explores the usefulness of the approach to support priority setting in a forestry context in Canada. The modeling framework makes use of both objective and subjective data embedded in a multi-region trade model. An important distinction is that regions are defined not only as countries but as ecological zones within which research occurs. This structure allows for a more explicit representation of factors such as lag periods, adoption rates, and spillover effects that influence the magnitude of benefits from research.

In this report several perspectives are taken in the analyses (i.e., national versus regional versus provincial benefits from research). These perspectives result in different priority rankings for research on forestry commodities. Several suggestions are made to make the approach more useful to Canadian research managers. These improvements are needed to distinguish the differences between competing choices about research projects and will be the focus of future efforts.

RÉSUMÉ

On décrit dans le rapport un modèle général qui produit des renseignements économiques quantitatifs sur les avantages qui découleraient de la recherche. Ce modèle ayant servi, dans un contexte international, à étayer les priorités de la recherche agricole, halieutique et forestière, on explore son utilité pour l'établissement des priorités dans le contexte de la foresterie au Canada. La modélisation repose à la fois sur des données objectives et sur des données subjectives, qui sont intégrées à un sous-modèle des échanges commerciaux entre plusieurs régions. Caractéristique importante, celles-ci ne sont pas seulement des pays; elles peuvent également être des zones écologiques à l'intérieur desquelles a lieu la recherche. Ce découpage permet de représenter de façon plus explicite les facteurs tels que les périodes de décalage, les vitesses d'adoption et les effets de propagation qui influent sur l'amplitude des avantages découlant de la recherche.

L'analyse procède de plusieurs points de vue (c'est-à-dire des avantages pour le pays, pour la région, pour la province, qui découlent de la recherche). Ces points de vue résultent des priorités différentes accordées à la recherche sur les produits forestiers. On propose plusieurs moyens pour rendre l'exercice plus utile aux directeurs des programmes de recherche au Canada. En effet, ces améliorations, auxquelles on s'astreindra, sont nécessaires pour pouvoir distinguer les différents choix qui s'opposent à l'égard des projets de recherche.

TABLE of CONTENTS

1. INTRODUCTION

In Canada there are a number of committees and groups that regularly comment on forestry research priorities at national and provincial levels (e.g., Forestry Research Advisory Council of Canada 1992). Recommendations on priorities are often very general and questions remain about the likely costs and benefits of research in different areas (Vertinsky *et al.* 1991). Thus there is an apparent growing need for recommendations, decisions, and strategies on research priorities to be complemented by systematic analysis. Since 1984 the Australian Centre for International Agricultural Research (ACIAR) has been developing a systematic information system to support decision making on research priorities. The context has primarily been international agricultural, fisheries, and forestry research. This report presents an application of the ACIAR framework to forestry research priority setting in Canada, and explores the usefulness of this approach.

The information system developed at ACIAR uses both objective and subjective data to allow decision makers to investigate the implications of research with different economic objectives, on different commodities, and in different ecological zones. The approach differs from other priority setting methods such as scoring models, congruence techniques, and resource cost analysis (Fox 1986). The intent of the information system, particularly the economic component, is to *support* decision making. It does *not* make decisions for, or replace, decision makers.

The report is structured as follows: Section 2 provides some background on research policy and a description of the underlying framework; Section 3 gives an example of an application of the model in an international context; illustrative examples of an application of the framework to forestry research in Canada are given in Section 4; Section 5 concludes the paper with some suggestions to improve the model for Canadian applications. There is relatively little literature on research evaluation and priority setting in forestry (see Huang and Teeter 1990; Hyde *et al.* 1992; Moore and Newstead 1992; and McKenney *et al.* 1992, 1993 for recent project evaluation case studies). An important objective of this paper is to contribute some quantitative analysis to the subject of forestry research priority setting.

2. RESEARCH POLICY AND PRIORITY SETTING

One important component of a nation's economic growth relates to its research and development policies (Mellor 1987). Such policies determine research priorities within a country. Figure 1 conceptualizes the research policy process from development, to implementation, to review.

Beginning at the national level, effort is primarily directed at the formulation of overall strategies. This includes the rationale for government intervention in research and hence the balance between public and private research activities. Where direct government intervention in research occurs, it is generally justified on both equity and efficiency grounds (Davis and Ryan 1987).

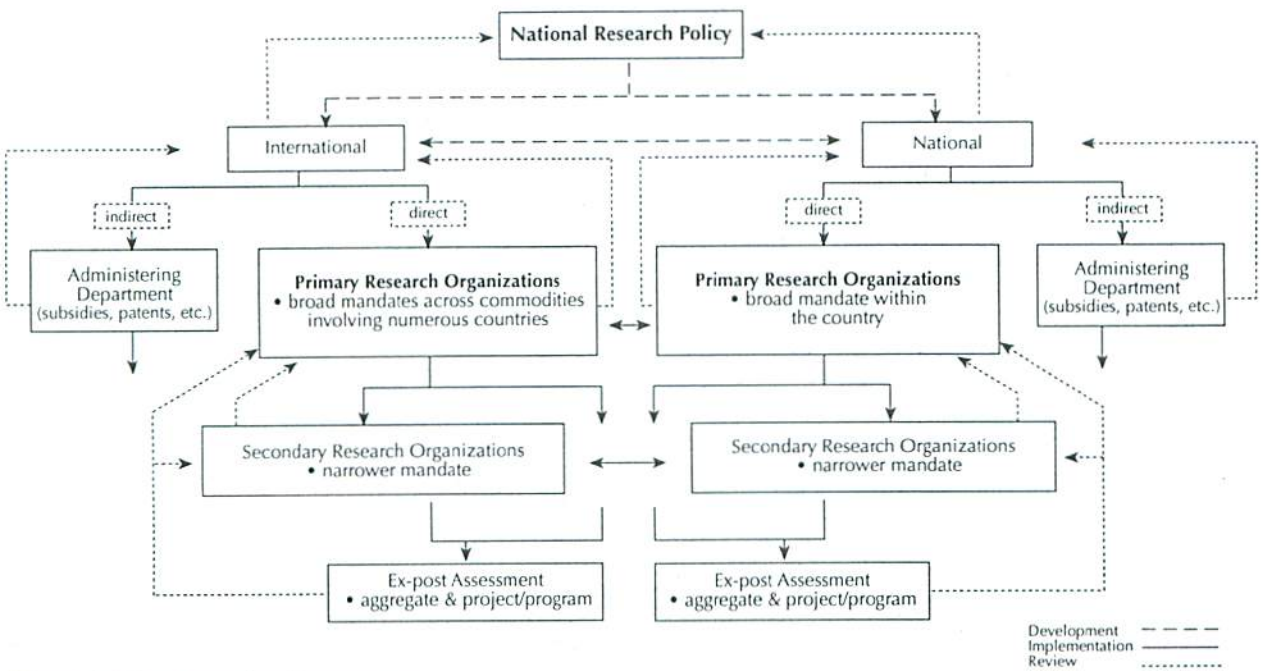

Figure 1. The research policy process.
Source: Davis and Ryan (1987).

Equity issues relate to the distribution of wealth to current and future generations (Bullard 1986). The general argument is that research contributes new knowledge or technology that can potentially benefit society (i.e., both producers and consumers) now, and in the future, and that market forces would not engage in research that would address intergenerational issues or nonmarket values. Efficiency issues often revolve around the ability or inability to appropriate (e.g., patent) the benefits of research. The general argument here is that, due to the nature of certain types of research, the private sector (e.g., individual firms) cannot capture enough benefits to justify its involvement. Therefore, research is often said to represent a classic example of market failure, thereby providing another rationale for government intervention.

Government intervention can be both direct and indirect. Examples include any combination of the creation and maintenance of research organizations, funding bodies, tax concessions, subsidies for private research, and the establishment of intellectual property rights to capture research benefits. Direct government intervention in the form of research organizations requires choices about numbers and locations (*see* primary and secondary research institutions in Figure 1). The mandates of primary research organizations are often quite broad. For example, within an agricultural research institution the research choices can involve emphasizing one commodity in a particular region over other commodities in other regions. Choices within a secondary research organization are generally narrower, often focusing on particular disciplines, programs, or projects within a given region and for a smaller set of commodities (Table 1).

Ideally, the process of development, implementation, and review of research policy and allocation decisions should be complementary and iterative. This could be achieved through ongoing monitoring, evaluation, and review by the responsible agencies while actual policy is being implemented.

ACIAR'S Decision Making Context

The Australian Centre for International Agricultural Research is an example of a primary research organization. It was created in 1982 to promote research on improving and sustaining agricultural, forestry, and fisheries production in developing countries[1]. Examples include growing food crops on nonirrigated lands, biological control of pests, identifying suitable fast-growing trees for fuelwood, alleviating land degradation, and assisting developing countries with pricing policies that encourage appropriate development. Thus for ACIAR, decisions are made that reflect judgments about, for example, the value of rice research in the Philippines, relative to potato research in Indonesia, or fuelwood research in Africa or China.

Forest Research in Canada

Natural Resources Canada, Canadian Forest Service is Canada's national forestry organization. Its mission is:"*To promote the sustainable development and competitiveness of the Canadian forest sector for the well being of present and future generations of Canadians.*"

Table 1. Research resource allocation decisions.

Level	Type of Decision
Primary	• commodity and regional emphases/balance
	• private/public balance
	• balance between basic, applied, strategic, development, and adaptive research
	• extent of centralization versus regional devolution
	• emphasis between short and long run outcomes
	• disciplinary balance
	• extent/emphasis on training and development
	• balance of national/international research
Primary and Secondary	• balance between current/capital/salary/nonsalary expenditures
	• location/number and size of research establishments
	• disciplinary balance
	• allocation of funds to commodities/disciplinary projects
Secondary	• balance between lab/forest research activities
	• balance between research/monitoring/evaluation and review activities
	• balance between review and extension activities

Source: adapted from Davis and Ryan (1987).

[1]A detailed description of ACIAR's decision-making environment, its evolution, and the information system is given in Davis and Ryan (1994).

To achieve this general aim, the organization engages in a variety of activities ranging from forest-based research to regional development initiatives and national tree-planting programs. Research emphases may vary regionally depending on local priorities, demands from and collaboration with clients, and the endowment of scientists at the research establishments. Compared to an organization like ACIAR, its range of possible research portfolios is narrow. Nevertheless, there is considerable latitude for research activities in forestry. An example is given with the range of research priorities set out annually by the Forest Research Advisory Council of Canada (FRACC). Priorities identified by FRACC in 1991 are set out below:

- Environmental effects of forest management
- Pest and weed management and alternatives to chemicals
- Decision support for management, silviculture, and land use
- Ecological knowledge for intensive forest management
- Integrated resource management systems
- Site productivity classification systems
- Growth and yield data for managed and unmanaged stands
- Silvicultural and harvesting methods and cost reduction
- Forest fire management and control
- Tree improvement and genetics
- Increasing forest productivity
- Wood processing and value added products

Clearly there is a range of scientific disciplines and forest outputs for which these priorities are relevant. However, a list such as this raises a number of questions. How were these priorities determined? Are the priorities ranked? What are the nonpriority areas? Why are they nonpriority areas? How does this list influence, support, or guide decision makers?

A Modeling Framework for Assessing Potential Research Benefits[2]

Within any research organization many factors will influence decision making. These include the past experience and training of decision makers, peer pressures, and client and political pressures. Because ACIAR funds research on numerous commodities in many parts of the world, its information system should provide some quantitative information on the international implications of alternative research choices. Figure 2 provides a schematic representation of the analytical component of the ACIAR information system.

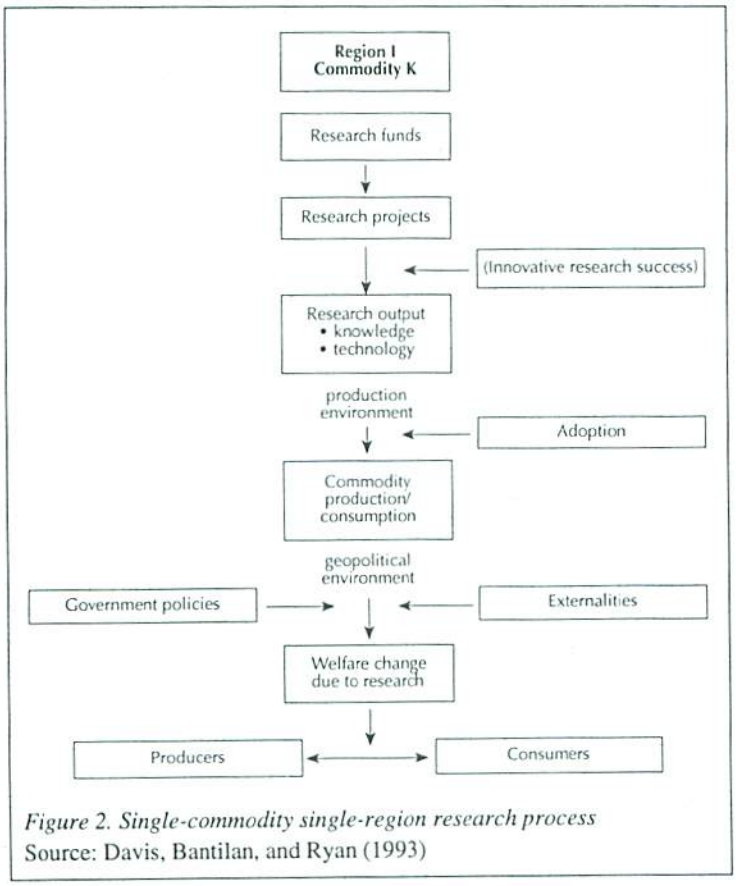

Figure 2. Single-commodity single-region research process
Source: Davis, Bantilan, and Ryan (1993)

Single-region, single-commodity example

To begin, first 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 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) and the research support to the nature of the problem under investigation. Whatever the reasons, the impact of the research would cease at this point.

If the research is successful, the output is generally new knowledge or technology that can, potentially, be used or *adopted*. Research success does not guarantee adoption by foresters or other decision makers. Results may be more costly than current practices or decision makers may be reluctant to change or require additional education. Thus the impact of even successful research can be diluted by non-adoption.

[2]This section is largely drawn from Davis *et al.* (1987), Davis and Fearn (1992), and Davis, Bantilan, and Ryan (1994).

Once developed and adopted, knowledge or technology can influence production from individual forests and 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. It is at this stage that the demand and supply conditions for the commodity become important components of the research process. Changes in these conditions can affect the economic welfare of different groups. In Figure 2 these groups are *consumers* and *producers*; however, in principle a range of disaggregations can be considered. The 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, and decreased soil erosion through alternative management practices, are two forestry examples.

Another factor that can influence welfare changes is existing government policies. These can influence production and consumption by affecting 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. To this point, we have been describing the research process for a single commodity in a single region. Such regions are usually geopolitically defined (e.g., Ontario).

Multiple-region, multiple-commodity example

It is better to consider the single region conceptualization described above to be an area or set of relatively homogeneous forest conditions. These can be termed *production environments*. In most countries forests and research projects extend across many geopolitical boundaries and ecological regions or production environments. This adds a number of dimensions to the research process. Figure 3 indicates some of these interactions via the linkages shown between regions I and J. While research may originate in one region, the knowledge or technology may be applicable to other regions. These are indicated as *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 result.

Again, if research results are adopted in other regions, production will be affected. Depending on market conditions and the impact of the research, the price of the commodity may change (i.e., *price spillovers*). 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 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. In Figure 3 this is indicated by the linkages between commodities K and L.

The first consideration of decision making in the research process characterized in Figure 3 relates to the notion of research objectives. Clearly, there is a range of welfare effects that can flow from any given research effort. These effects will vary according to commodity emphasis, production environment emphasis, and the type of research. Examples of different economic objectives include maximizing national benefits over regional benefits, or maximizing the benefits to particular groups (for ACIAR this might be poor farmers in developing countries, in Canadian forestry it may be producers in a particular region). Experience suggests that clearly defining, clarifying, and interpreting research objectives is a challenging, but critical component of establishing an effective information system.

The Information System in Use

ACIAR has been institutionalizing an information system based on the analytical framework represented in Figure 3. Development of the system was deemed useful for several reasons:

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

These issues are also relevant in the Canadian context. The information system is essentially two comprehensive databases. The first is a standard project management information system. Data on budgets, outputs, etc., are kept on individual projects. Manipulation of this database can provide information about the share of research funds to geographical regions and on particular commodities. Expenditure patterns through time can also be determined.

The second is a Research Evaluation Database (RED) which has been derived through modeling the potential *ex ante* (i.e., before the fact) benefits of research. It 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). The RED is a *multi-region* trade model and uses the economic concepts of consumer and producer surplus to estimate the potential welfare effects of research

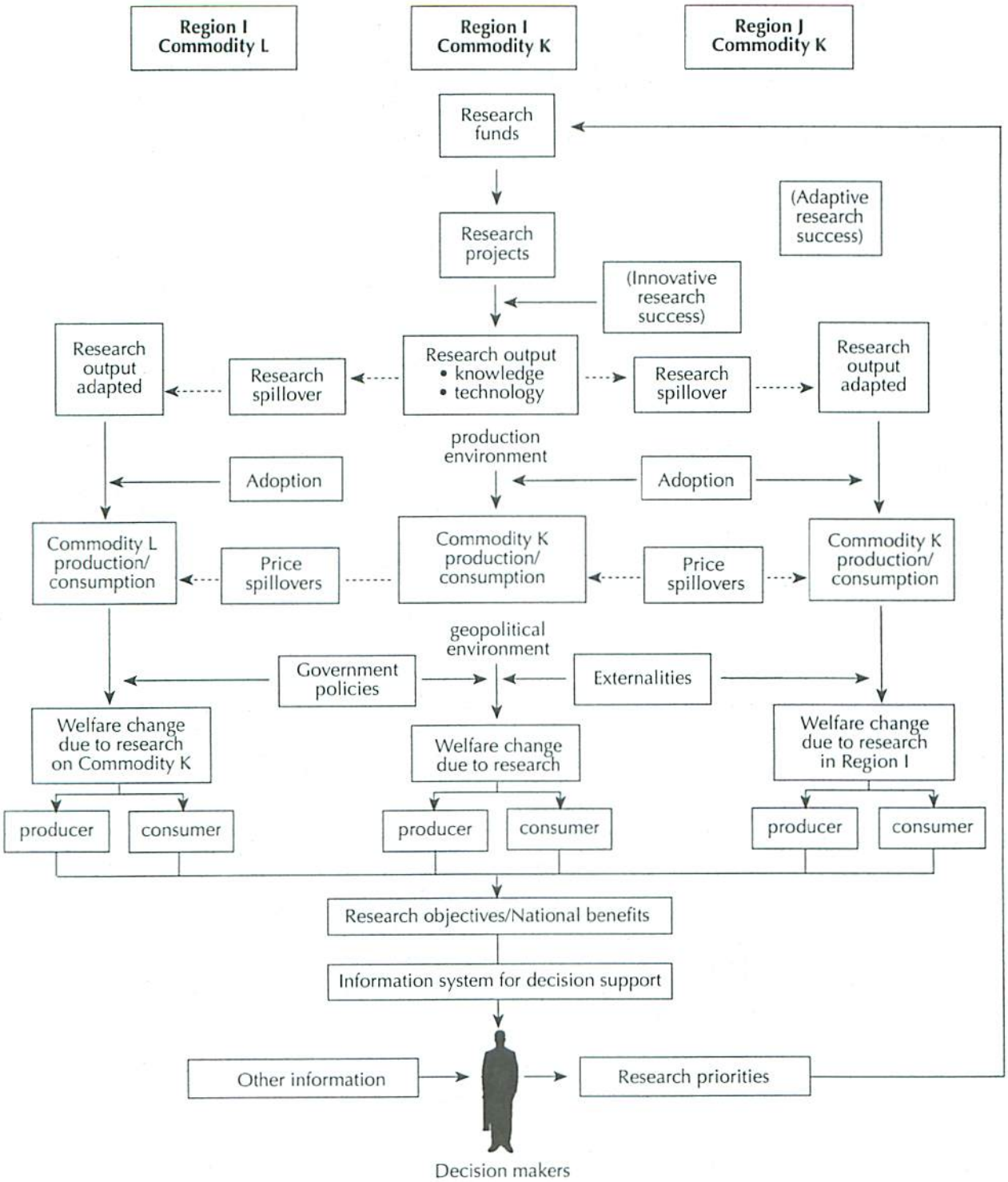

Figure 3. Research process and research decision making.
Source: Davis, Bantilan, and Ryan (1994).

as described above. A range of economic data (actual or estimates) is required to model these possible effects: defining a product or output, historical production and consumption levels, prices, and elasticities.

An important assumption in the following applications is that research results in a standard 5% 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 more obvious (e.g., the work of 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). In these cases, the lags may be different or the research may be relevant to a range of species and commodities.

Other technical data of the Research Evaluation Database focuses on perceived relative strengths of research systems, potential spillovers between production environments, and the potential adoption levels for the research outputs. Estimates of this type of information are obtained through consultations and consensus of research managers and technical experts.

In its current form at ACIAR, the Research Evaluation Database includes data and estimates of all parameters for all countries in the world for 44 commodities ranging from rice and cassava to fuelwood and prawns. ACIAR has assembled data into 75 countries or aggregations of countries. Eight forest products have been included:

- Fuelwood – coniferous (C) and nonconiferous (NC)
- Charcoal
- Pulpwood
- Sawlogs and veneer logs – (C) and (NC)
- Other industrial roundwood
- Pitprops

All eight are based on the United Nations Food and Agriculture delineation of forest products.[3] They were chosen to reflect forest-based research and avoid double counting and overestimating of benefits. This 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. Details of the data collection procedures and preliminary results are given in Davis, McKenney, and Turnbull (1989). Davis, McKenney, and Turnbull (1994) provide more technical details on the model and results from an international perspective. Appendix A contains additional information on data used to generate the results provided in this report.

Estimating Research Spillovers[4]

The concept of research spillovers was identified in Figure 3. The nature of the research will have an important impact on the potential spillovers. For example, the output of what is often referred to as "basic" research could be applicable in quite diverse production environments. On the other hand, some knowledge may be relevant only to specific environments. The spillovers used in this study refer to a mean of this distribution of effects. For some applications it may be necessary to develop several spillover matrices for each commodity and each type of research. This suggestion is elaborated upon in the concluding section.

The research spillover indexes are derived as a product of several matrices. These matrices contain information or estimates of: (1) potential research focus parameters (i.e., which production environments or ecological zones research could occur in), (2) expected production environment spillover indexes, (e.g., the *likely* relevance of research in one ecological zone to other ecological zones), and (3) commodity production shares for each country or region by production environment. The resulting spillover index matrix is the potential spillover effect of research in one region on production in other regions.

Discussions with various forestry experts led ACIAR to adapt the agroclimatic classification developed by Papadakis (1975) as the basic definition of production environments for its international forestry analysis. Clearly, decision makers in some countries could prefer other classifications. There are ongoing efforts to refine this production environment classification scheme to ensure maximum consistency of forestry with other products. Papadakis classified the world's agroclimatic conditions into 10 broad categories. Zone 1 includes tropical environments and Zone 10 includes polar categories. Within each of those zones there are up to nine single decimal subzones that include separations based on factors such as altitude and temperature. Although the system is available to a four decimal classification, the single decimal classification was used in this study. Much of Canada's northern areas are in Zones 9 and 10. Maritime areas are mostly in Zone 7 and much of southern Quebec and Ontario are in Zone 8.

3. ILLUSTRATIVE RESULTS FROM AN INTERNATIONAL ANALYSIS

The Research Evaluation Database is capable of generating an extensive amount of information. To support decision making, summary reports are required. Results need to be displayed in a way that provides insights on some of the trade-offs involved in different funding patterns. Considerable effort has been placed on the generation of summary tables but this is an evolutionary process as

[3] International production and consumption data for each of these product categories were obtained from the United Nations Food and Agriculture Organization's computer tapes (e.g., FAO 1993). Production data for Canada are from Statistics Canada (Catalog # 25-201). Consumption was derived using import/export data from the External Trade Division of Statistics Canada (Consumption = Production + Imports - Exports). Sawlogs and veneer logs are logs and bolts in Statistics Canada nomenclature.

[4] Further details of the concept of research spillovers and the model used to estimate these are contained in Davis (1991); Davis and Ryan (1994); Davis, McKenney, and Turnbull (1994); and briefly in the Appendix.

the requirements of decision makers will change through time. Tables 2 and 3 provide some illustrative results comparing potential benefits of forestry research and agricultural research.

Table 2 shows the monetary measures of the potential regional gains from research if it is undertaken on problems relevant to that region and generates a 5% unit cost reduction for each of the commodities listed. The regions in Table 2 relate to ACIAR's interests. A 30-year time horizon and 12% discount rate were used in these net present value calculations. Table 2 shows that rice research is important in many regions, but the rankings of commodities vary by region. An alternative format has been found to be more intuitively useful: *"break-even relativities"*, shown in Table 3. The relativities are calculated by ordering the commodities from highest benefits to lowest and then dividing the highest value by the value for that commodity. For example, the break-even relativity for rice in South Asia is 1 (421÷421). A 5% unit cost reduction is expected to provide regional welfare gains to South Asia of $421 million (U.S) (30-year planning horizon and a real discount rate of 12%). For nonconiferous sawlogs and veneer logs in the same region, the potential benefits from a 5% unit cost reduction amount to $38 million (U.S.). This translates to a break-even relativity of 11 (421÷38). In other words, research on sawlogs and veneer logs would have to generate 11 times the percentage cost reduction to provide the same regional welfare gains as rice research. The break-even relativities abstract from the arbitrary use of the 5% unit cost reduction.

Table 3 also includes the break-even relativities between geographical regions. This is calculated by dividing the highest regional welfare gains (rice in China) by each of the highest gains in the other regions. It shows that for tuna and bonitos research in the South Pacific to generate the same welfare gains as rice research in China, about 200 times the percentage unit cost reduction would be required. These relativities quantify some of the trade-offs involved in choosing research projects in different parts of the world and on various commodities.

It has proven useful to identify priority groupings rather than just a listing of the relativities. Six priority groupings are used here. Priority group 1 has a range of break-even relativities of 1 to 10; 2 is 11–20; 3 is 2–40; 4 is 41–80; 5 is 81–160; and 6 is greater than 160. For the regions presented, forestry products show up in all six priority groupings.

The information shown in Tables 2 and 3 is *not* used to dictate that research should only occur on the highest ranking commodities. The identified priorities can be used in planning discussions to generate and focus debate. The rankings assume the same relative cost-reducing impact of the research for all agricultural and forestry products. For regions that have had little forestry research compared to that for agricultural commodities, some forestry research may in fact have a greater potential cost-reducing impact. On the other hand, some types of forestry research are likely to have longer lag periods than agricultural research. Increasing the lag periods could reduce the present value of the research benefits. One trend has been to develop more detailed economic assessments of those projects included with the scientific components of the research proposals. This trend is evident in the Canadian Forest Service where funding of research associated with some development agreements has required cursory economic assessments.

Information presented in Table 2 assumes that research on one commodity does not affect other products. If research is likely to have an impact on more than one product, for example work on tree species that are grown for both fuelwood and pulpwood, then the benefits should be combined.

4. ILLUSTRATIVE RESULTS FROM A CANADIAN APPLICATION

This section discusses some *illustrative, preliminary* results generated for Canadian applications of an ACIAR-type model. The subjective input data for the Canadian analyses uses the ACIAR sources and assumptions. Future plans include refining these data to better suit particular regions interested in this type of information system.

For the Canadian analyses, provincial production and consumption data were collected or derived from Statistics Canada (1983–85) catalogues for six products:

- Fuelwood - coniferous and nonconiferous (C and NC)
- Pulpwood
- Sawlogs and veneer logs - C and NC (this corresponds to logs and bolts, softwood and hardwood from Statistics Canada)
- Other industrial roundwood

Canada was separated into 11 individual regions (each province as a region and the two territories as one region). Results addressing the following issues are included here:

- National and international benefits from Canadian research for many of the commodities in the ACIAR database (this provides some indication of the relative importance of forestry versus agricultural or fisheries research nationally and internationally)
- National benefits from research in forestry
- Regional benefits from research in those regions
- Provincial benefits from research in those provinces
- National benefits from research in particular provinces
- International benefits from research in particular provinces
- Regional benefits from research in particular production environments in those regions

The potential benefits from research are calculated over a 30-year time horizon using an 8% real discount

Table 2. Gross present value of regional welfare benefits for a regional research focus[a].

South Asia		Southeast Asia		China		South Pacific	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Rice	421	Rice	200	Rice	1157	Tunas, bonitos, etc.	6
Milk	269	Sawlogs & veneer logs (NC)	181	Pigmeat	594	Fuelwood (NC)	6
Fuelwood (NC)	204	Fuelwood (NC)	167	Sweet potato	311	Sawlogs & veneer logs (NC)	4
Wheat	131	Palm oil/kernel	96	Maize	277	Sugar	2
Pulses all	115	Rubber	64	Potatoes	237	Banana/plantain	1
Potatoes	63	Sugar	23	Wheat	233	Palm oil/kernel	1
Cotton	52	Coconut	22	Cotton	130	Coffee	1
Sugar	50	Banana/plantain	20	Eggs (poultry)	102	Cocoa	1
Sawlogs & veneer logs (NC)	38	Cassava	16	Soybean	60	Demersal/other	0
Sorghum	37	Pigmeat	14	Pulses all	59	Pigmeat	0
Groundnut	35	Deaersal/other	13	Fuelwood (NC)	59	Coconut	0
Millet	24	Prawns/shrimps	13	Sawlogs & veneer logs (C)	45	Pulpwood	0
Sheep & goat meat	24	Maize	12	Sugar	44	Sawlogs & veneer logs (C)	0
Banana/plantain	20	Eggs (poultry)	11	Fuelwood (C)	40	Sweet potato	0
Maize	18	Coffee	11	Poultry meat	37	Milk	0
Beef & buffalo	16	Poultry meat	10	Sheep & goat meat	30	Prawns/shrimps	0
Eggs (poultry)	15	Beef & buffalo	8	Groundnut	29	Rice	0
Prawns/shrimps	14	Tilapias	7	Sawlogs & veneer logs (NC)	28	Tilapias	0
Coconut	13	Cocoa	7	Milk	25	Beef & buffalo	0
Desersal/other	8	Other ind. roundwood	6	Other ind.roundwood	19	Cassava	0
Oranges & tangarines	8	Tunas, bonitos, etc.	4	Prawns/shrimps	17	Charcoal	0
Herrings & other	7	Mackerals & other	3	Millet	14	Cotton	0
Cassava	6	Charcoal	3	Sorghum	13	Eggs (poultry)	0
Fuelwood (C)	6	Sheep & goat meat	3	Wool	12	Fuelwood (C)	0
Sawlogs & veneer logs (C)	6	Herrings & other	3	Oranges & tangarines	9	Groundnut	0
Soybean	6	Soybean	2	Beef & buffalo	8	Herrings & other	0
Charcoal	6	Milk	2	Pitprops	7	Lobsters	0
Other ind. roundwood	4	Pulpwood	2	Mackerels & other	5	Mackerals & other	0
Wool	3	Sweet potato	2	Demersal/other	5	Maize	0
Poultry meat	3	Pulses all	1	Cassava	4	Millet	0
Coffee	3	Sawlogs & veneer logs (C)	1	Rubber	4	Oranges & tangarines	0
Tilapias	3	Groundnut	1	Palm oil/kernel	4	Other ind. roundwood	0
Pigmeat	3	Cotton	1	Pulpwood	3	Pitprops	0
Rubber	2	Oranges & tangarines	1	Tunas, bonitos, etc.	3	Potatoes	0
Pitprops	1	Lobsters	1	Banana/plantain	1	Poultry meat	0
Pulpwood	1	Potatoes	0	Coffee	0	Pulses all	0
Sweet potato	1	Sorghum	0	Herrings & other	0	Rubber	0
Mackerals & other	1	Wheat	0	Charcoal	0	Sheep & goat meat	0
Tunas, bonitos etc.	1	Millet	0	Cocoa	0	Sorghum	0
Lobsters	0	Fuelwood (C)	0	Coconut	0	Soybean	0
Cocoa	0	Pitprops	0	Lobsters	0	Wheat	0
Palm oil/kernel	0	Wool	0	Tilapias	0	Wool	0

[a] Welfare measure in $ million (U.S.) over 30 years with 12% discount rate.

Source: Davis and Fearn (1992)

Table 3. Regional commodity research priority grouping for a regional benefits objective – break-even relativities.

South Asia			Southeast Asia			China			South Pacific		
Priority group	Commodity ranking	Regional benefits	Priority group	Commodity ranking	Regional benefits	Priority group	Commodity ranking	Regional benefits	Priority group	Commodity ranking	Regional benefits
	Rice	1		Rice	1		Rice	1		Tunas, bonitos, etc.	1
	Milk	2		Sawlogs & veneer logs (NC)	1		Pigmeat	2		Fuelwood (NC)	1
	Fuelwood (NC)	2		Fuelwood (NC)	1		Sweet potato	4		Sawlogs & veneer logs (NC)	1
	Wheat	3	1	Palm oil/kernel	2	1	Maize	4	1	Sugar	3
1	Pulses all	4		Rubber	3		Potatoes	5		Banana/plantain	4
	Potatoes	7		Sugar	9		Wheat	5		Palm oil/kernel	6
	Cotton	8		Coconut	9		Cotton	9		Coffee	7
	Sugar	8		Banana/plantain	10						
							Eggs (poultry)	11		Cocoa	12
	Sawlogs & veneer logs (NC)	11		Cassava	12		Soybean	19	2	Demersal/other	20
	Sorghum	11		Pigmeat	14		Pulses all	20		Pigmeat	20
2	Groundnut	12		Demersal/other	15		Fuelwood (NC)	20			
	Millet	17	2	Prawns/shrimps	16					Coconut	30
	Sheep & goat meat	18		Maize	16		Sawlogs & veneer logs (C)	26	3	Pulpwood	30
				Eggs (poultry)	18		Sugar	26		Sawlogs & veneer logs (C)	30
	Banana/plantain	21		Coffee	18	3	Fuelwood (C)	29		Sweet potato	30
	Maize	23		Poultry meat	19		Poultry meat	31			
3	Beef & buffalo	27					Sheep & goat meat	39		Milk	59
	Eggs (poultry)	27		Beef & buffalo	25		Groundnut	40	4	Prawns/shrimps	59
	Prawns/shrimps	30	3	Tilapias	27					Rice	59
	Coconut	33		Cocoa	28		Sawlogs & veneer logs (NC)	41		Tilapias	59
				Other ind. roundwood	33	4	Milk	46			
	Desersal/other	53					Other ind. roundwood	62			
	Oranges & tangarines	55		Tunas, bonitos, etc.	57		Prawns/shrimps	67		Beef & buffalo	0
	Herrings & other	64		Mackerals & other	61					Cassava	0
4	Cassava	67	4	Charcoal	63		Millet	81		Charcoal	0
	Fuelwood (C)	67		Sheep & goat meat	65		Sorghum	89		Cotton	0
	Sawlogs & veneer logs (C)	67		Herrings & other	67	5	Wool	97		Eggs (poultry)	0
	Soybean	75					Oranges & tangarines	129		Fuelwood (C)	0
	Charcoal	77		Soybean	83		Beef & buffalo	139		Groundnut	0
				Milk	95					Herrings & other	0
	Other ind. roundwood	98	5	Pulpwood	111		Pitprops	163		Lobsters	0
	Wool	136		Sweet Potato	133		Mackerels & other	214		Mackerals & other	0
5	Poultry meat	140		Pulses all	143		Demersal/other	227		Maize	0
	Coffee	145		Sawlogs & veneer logs (C)	143		Cassava	275	6	Millet	0
	Tilapias	156					Rubber	275		Oranges & tangarines	0
				Groundnut	167		Palm oil/kernel	289		Other ind. roundwood	0
	Pigmeat	162		Cotton	200		Pulpwood	413		Pitprops	0
	Rubber	183		Oranges & tangarines	222	6	Tunas, bonitos, etc.	463		Potatoes	0
	Pitprops	301		Lobsters	286		Banana/plantain	1286		Poultry meat	0
	Pulpwood	324		Potatoes	500		Coffee	5785		Pulses all	0
	Sweet potato	351	6	Sorghum	500		Herrings & other	5785		Rubber	0
6	Mackerals & other	421		Wheat	667		Charcoal	0		Sheep & goat meat	0
	Tunas, bonitos, etc.	842		Millet	2000		Cocoa	0		Sorghum	0
	Lobsters	2105		Fuelwood (C)	0		Coconut	0		Soybean	0
	Cocoa	4210		Pitprops	0		Lobsters	0		Wheat	0
	Palm oil/kernel	0		Wool	0		Tilapias	0		Wool	0
Regional relativities		2.7			5.8			1.0			196.1

Source: Davis and Fearn (1992)

rate. Interpreting the results requires careful consideration of the underlying assumptions (e.g., lags, spillovers). It is noteworthy that the process of obtaining results is as important, if not more important, than the results themselves because of the questions the framework provokes.

National and International Benefits from Canadian Research

Table 4 lists potential benefits to Canada generated by research in Canada on many of the commodities in the ACIAR database. A number of agricultural commodities in the database are not produced in Canada and some agricultural commodities produced here are not included in this analysis (e.g., canola). Table 4 shows that the potential benefits of forestry research can be as great as those of agricultural research. In fact, research on coniferous sawlogs and veneer logs generates the most potential benefits in this particular mix of commodities. Several caveats should be noted with this conclusion. The issue of the differential lag periods has already been mentioned; that is, the lags for certain types of forestry research may be longer than with agricultural or fisheries research. Also, an artifact of the Statistics Canada data is that British Columbia includes pulpwood in its coniferous sawlogs and veneer logs production estimates. Thus the total Canadian production of coniferous sawlogs and veneer logs may be greater than it should be. The extent to which coniferous sawlogs and veneer logs research and pulpwood research are separable means that the potential benefits in the coniferous sawlogs and veneer logs category could be overestimated.

Table 4 shows that benefits to other parts of the world can be an important component of the overall gains from research. This potential distribution of benefits is a function of production and consumption of these commodities in the other regions, the degree of similarity to Canadian production environments, and therefore potential spillover effects of Canadian research to those countries. In some cases, the likely gains from research in Canada are greater in other regions. This is because those regions have large production levels in environments similar to Canada. The generation of spillover benefits such as these provides one rationale for publicly funded research, but these results also demonstrate the potential for both winners and losers (i.e., note the negative values in Table 4) from research efforts.

In Canada, agricultural, forestry, and fisheries research is conducted by separate organizations. The following sections focus only on the potential benefits from forestry research. Some spillovers may occur between forestry and agriculture or fisheries research programs, suggesting a potential for interagency collaborative projects.

Regional Benefits from Regional Research Programs

Table 5a presents the results of the research evaluation model for regional benefits from regional research programs. These regional delineations are arbitrary and could be changed.

Eastern: Newfoundland, New Brunswick, Prince Edward Island, and Nova Scotia
Central: Quebec and Ontario
Prairies: Manitoba, Saskatchewan, and Alberta
Western: British Columbia, Yukon, and Northwest Territories

Results show that coniferous sawlogs and veneer logs and pulpwood oriented research dominates potential benefits for all regions. Western and Central Canada generate the most benefits from forestry research. The magnitude of the potential benefits from research on nonconiferous sawlogs and veneer logs in Central Canada relative to other products and regions stands out.

Table 5b presents the break-even relativities, which indicate the importance of research on each commodity relative to the highest-gain commodity. For example, all other factors being equal, research on nonconiferous sawlogs and veneer logs in Eastern Canada would require about 16 times the unit-cost reduction to generate the same magnitude of benefits as research on coniferous sawlogs and veneer logs. If these two commodities had the same production costs, and research on coniferous sawlogs and veneer logs resulted in a $1 unit-cost reduction, then nonconiferous sawlogs and veneer logs research would require a unit-cost reduction of $16 to generate the same overall level of benefits. This result is due to relative production levels, costs, and the production environments.

It is noteworthy that fuelwood ranks quite high in both Eastern and Central Canada. This is a reflection of fuelwood production levels in those regions. As emphasised earlier, break-even relativities do not necessarily imply that research is *not* worthwhile on the lower ranking commodities. The numbers are a *relativity* scale based on the assumption of a *standard* cost-reducing impact due to research. Case studies are required to assess actual unit-cost reductions and provide a more rigorous basis for some of the subjective values used in this application.

National Benefits for Canada from Regionally Focused Research

Table 6 is similar to Table 5 except that the benefits and priority groupings relate to the nation as a whole rather than specific regions. The results include benefits accruing to all regions from research in that region. Clearly, spillover effects to other parts of the country are significant. Western and Central Canada have similar regional break-even relativities. The regional relativities

Table 4. National and international benefits from Canadian research[a].

Commodity	Canada	All developing	South Asia	Southeast Asia	China	South Pacific	Africa	West Asia North Africa	Latin America
Fuelwood (C)	1.4	9.3	0	0	9	0	0	0.3	0
Fuelwood(NC)	4.1	14	0.6	0	12.9	0	0	0.3	0.3
Other ind. roundwood	1.2	4.3	0	0	4.1	0	0	0.1	0.1
Pitprops	0	1.6	0	0	1.6	0	0	0	0
Pulpwood	34.8	0.7	0	0	0.6	0	0	0	0.1
Sawlogs & veneer logs (C)	238.5	11.8	0	0	11.4	0	0	0.4	0
Sawlogs & veneer logs (NC)	10.8	5	0	-1.2	6.3	-0.1	-0.3	0.1	0.2
Maize	25.5	59.6	0.5	-0.8	50.7	0	1.4	1.4	6.5
Potatoes	24.5	57.3	0.1	0.1	52.9	0	0.1	1.8	2.3
Beef & buffalo	77.8	3	0.6	0.1	2.7	0.1	0.2	1.1	-1.7
Cotton seed	0.6	6.3	1.9	0	3.5	0	0.1	0.2	0.6
Milk	100.7	58.3	7	4.2	9	0.1	4.5	14.1	19.3
Wheat	102.5	66.2	1.4	1.3	43.9	0.1	1.9	10	7.6
Pulses all	4.8	35.4	5.7	-0.5	26.7	0	0.1	0.9	2.6
Soybean	6.5	1	0	0.2	1.6	0	0	0	-0.9
Sugar	2.2	-4.8	0.2	-1.6	2.6	-0.3	-0.3	2.8	-8.2
Tunas, bonitos, etc.	0	0.5	0	0.3	0	0.1	0	0	0
Mackerals & others	1	3.1	0	0	0.6	0.2	0.4	0.6	1.3
Prowns/shrimps	3	4.1	0.5	2.5	0.1	0	0.1	0.1	0.7
Lobsters	20.6	0.8	0	0.1	0	0	0	0	0.6
Herrings & others	9.3	6	0.6	0.7	0	0	0.4	0.3	3.9
Demersal/other pelagic	29.3	1.3	0	0	0.2	0	0	0.1	1.1
Mussels	0	1.1	0	0.5	0.4	0	0	0	0.2
Oysters	1.4	2.8	0	0.9	0	0	0	0	1.9
Clams	2.2	4.5	0	3.1	0	0	0	0	1.3

[a]Net present value $ million (U.S.) over a 30-year period using an 8% discount rate.

are much closer than in Table 5. The Prairies have a regional relativity of 1.8, which means that a project there would have to have about twice the unit-cost reduction to generate the same level of benefits to all of Canada as research in Central or Western Canada. Again, the results are a reflection of relative production levels in the different production environments.

Tables 5 and 6 indicate little divergence between national or regional research objectives in terms of target commodities. For all regions, sawlogs and veneer logs (C) and pulpwood are the highest priorities. However, maximizing national objectives may increase the emphasis of nonconiferous sawlogs research in Eastern Canada. What may be of more interest to some is the potential divergence between provincial and national research objectives. This issue is examined in the next two sections.

Provincial Benefits from Research

Table 7 represents a further separation of the type of analyses shown in Table 5b. The break-even relativities are shown for each province from research in that province. The relativities between provinces indicate that research in British Columbia and Quebec is likely to generate the greatest level of benefits to those provinces, followed by Ontario, Alberta, and New Brunswick. For most provinces sawlogs and veneer logs (coniferous) has the highest priority ranking. Decision makers may want to consider the relativities between coniferous and non-coniferous tree species research; in Ontario, Quebec, Manitoba, and Saskatchewan there are fewer differences in the priority rankings among these categories than may be expected.

National Benefits from Research Focused in the Provinces

Table 8 presents relativity estimates of national benefits for research undertaken in particular provinces and provides a further breakdown of the regional results given in Table 6b. The relative importance of national versus provincial production levels becomes more evident in these tables. Coniferous sawlog and veneer log research ranks first in all provinces. This was not the case in Table 7, which only examined provincial benefits.

One purpose of these tables is to illustrate the potential dichotomy of differing research objectives such as national versus regional or provincial. Where there is potential disagreement among these objectives, projects may need to be designed to examine problems associated with more than one commodity or tree species. With maximizing national benefits as the objective, research in Quebec ranks slightly ahead of B.C. and Ontario; however, maximizing provincial benefits would rank B.C. slightly ahead of Quebec and Ontario. The break-even relativities are larger when provincial benefits are the research objective. This result is a reflection of the dominance of a single

Table 5a. Regional benefits for Canada.

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C)	25	Sawlogs & veneer logs (C)	227	Sawlogs & veneer logs (C)	41	Sawlogs & veneer logs (C) and pulpwood	259
Pulpwood	23	Pulpwood	71	Pulpwood	7	Sawlogs & veneer logs (NC)	2
Fuelwood (C)	3	Sawlogs & veneer logs (NC)	43	Sawlogs & veneer logs (NC)	3	Fuelwood (C)	0
Fuelwood (NC)	2	Fuelwood (NC)	16	Other ind. roundwood	1	Other ind. roundwood	0
Sawlogs & veneer logs (NC)	2	Other ind. roundwood	4	Fuelwood (C)	0	Fuelwood (NC)	0
Other ind. roundwood	0	Fuelwood (C)	3	Fuelwood (NC)	0		

Table 5b. Regional benefits for Canada – relativities.

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C) and pulpwood	1.0
Pulpwood	1.1	Pulpwood	3.2	Pulpwood	6.3	Sawlogs & veneer logs (NC)	123.3
Fuelwood (C)	9.6	Sawlogs & veneer logs (NC)	5.3	Sawlogs & veneer logs (NC)	12.1	Fuelwood (C)	647.5
Fuelwood (NC)	12.5	Fuelwood (NC)	14.3	Other ind. roundwood	51.4	Other ind. roundwood	647.5
Sawlogs & veneer logs (NC)	15.6	Other ind. roundwood	54.0	Fuelwood (C)	102.8	Fuelwood (NC)	0.0
Other ind. roundwood	83.3	Fuelwood (C)	78.2	Fuelwood (NC)	102.8		
Regional relativities	10.1		1.1		6.3		1.0

Table 6a. National benefits from provincial research – regional average.

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C)	199	Sawlogs & veneer logs (C)	296	Sawlogs & veneer logs (C)	167	Sawlogs & veneer logs (C) and pulpwood	290
Pulpwood	58	Pulpwood	86	Pulpwood	32	Fuelwood (NC)	4
Sawlogs & veneer logs (NC)	7	Sawlogs & veneer logs (NC)	44	Sawlogs & veneer logs (NC)	13	Sawlogs & veneer logs (NC)	3
Fuelwood (NC)	4	Fuelwood (NC)	16	Fuelwood (NC)	6	Fuelwood (C)	1
Fuelwood (C)	3	Other ind. roundwood	5	Other ind. roundwood	2	Other ind. roundwood	1
Other ind. roundwood	3	Fuelwood (C)	3	Fuelwood (C)	1		

Table 6b. National benefits by region – relativities.

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C) and pulpwood	1.0
Pulpwood	3.5	Pulpwood	3.4	Pulpwood	5.3	Fuelwood (NC)	76.4
Sawlogs & veneer logs (NC)	29.6	Sawlogs & veneer logs (NC)	6.7	Sawlogs & veneer logs (NC)	12.7	Sawlogs & veneer logs (NC)	100.1
Fuelwood (NC)	56.7	Fuelwood (NC)	18.0	Fuelwood (NC)	26.5	Fuelwood (C)	223.3
Fuelwood (C)	70.9	Other ind. roundwood	61.6	Other ind. roundwood	98.1	Other ind. roundwood	223.3
Other ind. roundwood	79.4	Fuelwood (C)	92.3	Fuelwood (C)	128.2		
Regional relativities	1.5		1.0		1.8		1.0

Table 7. Provincial benefits – relativities.

Newfoundland		Prince Edward Island		Nova Scotia		New Brunswick	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Pulpwood	1.0	Fuelwood (NC)	1.0	Pulpwood	1.0	Sawlogs & veneer logs (C)	1.0
Sawlogs & veneer logs (C)	2.8	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.1	Pulpwood	1.1
Fuelwood (C)	3.1	Fuelwood (C)	3.7	Fuelwood (NC)	9.1	Sawlogs & veneer logs (NC)	24.0
Fuelwood (NC)	21.0	Pulpwood	5.5	Sawlogs & veneer logs (NC)	16.0	Fuelwood (NC)	52.0
Other ind. roundwood	0.0	Sawlogs & veneer logs (NC)	11.0	Fuelwood (C)	42.7	Other ind. roundwood	78.0
Sawlogs & veneer logs (NC)	0.0	Other ind. roundwood	0.0	Other ind. roundwood	0.0	Fuelwood (C)	104.0
Regional relativities	32.3		25.9		19.9		8.3

Quebec		Ontario		Manitoba		Saskatchewan	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	4.6	Pulpwood	1.7	Pulpwood	1.5	Pulpwood	1.9
Sawlogs & veneer logs (NC)	10.2	Sawlogs & veneer logs (NC)	2.4	Sawlogs & veneer logs (NC)	3.0	Sawlogs & veneer logs (NC)	6.5
Fuelwood (NC)	17.4	Fuelwood (NC)	9.0	Fuelwood (NC)	10.0	Other ind. roundwood	9.0
Other ind. roundwood	48.1	Fuelwood (C)	45.9	Other ind. roundwood	15.0	Fuelwood (C)	18.0
Fuelwood (C)	101.0	Other ind. roundwood	413.5	Fuelwood (C)	30.0	Fuelwood (NC)	24.0
Regional relativities	1.2		3.1		89.3		35.9

Alberta		British Columbia		Yukon/Northwest Territories	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C) and pulpwood	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	10.5	Sawlogs & veneer logs (NC)	123.4	Fuelwood (C)	2.0
Sawlogs & veneer logs (NC)	14.4	Other ind. roundwood	647.8	Other ind. roundwood	8.0
Fuelwood (C)	216.0	Fuelwood (C)	0.0	Fuelwood (NC)	0.0
Fuelwood (NC)	432.0	Fuelwood (NC)	0.0	Pulpwood	0.0
Other ind. roundwood	432.0			Sawlogs & veneer logs (NC)	0.0
Regional relativities	5.9		1.0		323.0

Table 8. National benefits by province – relativities.

Newfoundland		Prince Edward Island		Nova Scotia		New Brunswick	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	6.3	Pulpwood	9.1	Pulpwood	6.4	Pulpwood	2.7
Fuelwood (C)	35.9	Fuelwood (NC)	46.4	Fuelwood (NC)	44.8	Sawlogs & veneer logs (NC)	29.4
Sawlogs & veneer logs (NC)	51.2	Sawlogs & veneer logs (NC)	50.8	Sawlogs & veneer logs (NC)	46.6	Fuelwood (NC)	42.1
Fuelwood (NC)	53.8	Fuelwood (C)	56.2	Fuelwood (C)	58.9	Other ind. roundwood	81.5
Other ind. roundwood	1076.0	Other ind. roundwood	1067.0	Other ind. roundwood	1119.0	Fuelwood (C)	90.5
Regional relativities	2.9		3.0		2.8		1.3

Quebec		Ontario		Manitoba		Saskatchewan	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	3.9	Pulpwood	2.8	Pulpwood	4.9	Pulpwood	5.0
Sawlogs & veneer logs (NC)	7.9	Sawlogs & veneer logs (NC)	5.4	Sawlogs & veneer logs (NC)	9.8	Sawlogs & veneer logs (NC)	11.8
Fuelwood (NC)	18.4	Fuelwood (NC)	16.3	Fuelwood (NC)	20.2	Fuelwood (NC)	35.3
Other ind. roundwood	65.9	Fuelwood (C)	79.1	Other ind. roundwood	86.7	Other ind. roundwood	83.0
Fuelwood (C)	95.9	Other ind. roundwood	79.1	Fuelwood (C)	90.5	Fuelwood (C)	108.5
Regional relativities	1.0		1.2		1.5		2.2

Alberta		British Columbia		Yukon/Northwest Territories	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C) and pulpwood	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	6.0	Sawlogs & veneer logs (NC)	100.2	Fuelwood (NC)	38.8
Sawlogs & veneer logs (NC)	14.5	Other ind. roundwood	223.5	Fuelwood (C)	113.5
Fuelwood (NC)	54.4	Fuelwood (NC)	290.5	Other ind. roundwood	113.5
Other ind. roundwood	129.7	Fuelwood (C)	0.0	Pulpwood	0.0
Fuelwood (C)	153.3			Sawlogs & veneer logs (NC)	0.0
Regional relativities	1.9		1.1		2.1

production environment in Quebec forestry (i.e., boreal) as compared to B.C. and Ontario where production environments are more heterogeneous.

International Benefits for Research Focused in the Provinces

Table 9 shows the relativities of potential international benefits of research undertaken in the provinces and territories. The rankings of commodities vary from previous tables, demonstrating the degree of similarity of individual provinces' production environments with other parts of the world. Research in Quebec, New Brunswick, and Ontario has the greatest potential for generating international benefits given the type of spillovers specified through the Papadakis (1975) climatic classification.

Regional Benefits for Research Focused on Particular Production Environments

The results presented thus far assume that the research focus is distributed throughout production environments in the same proportion as the production itself. In other words, if 10% of the production of the commodity comes from climatic Zone 9.3, for example, then 10% of the research funding would be focused on issues of importance to this climatic zone. The modeling approach allows research to be focused on production environments in any specified proportion. To illustrate, consider the results shown in Tables 10a and b. Research on three commodities, sawlogs and veneer logs (coniferous and nonconiferous) and pulpwood, was specified to focus on four particular production environments. The three commodities were deemed to be of most interest to decision makers in light of the results provided in previous tables. The four production environments included were: 7.7, which mostly occurs in maritime areas of Newfoundland and Nova Scotia; 8.3, which occurs through the Maritimes, Quebec, and Ontario; 9.3, which occurs primarily in the Prairies; and 10.1, which extends across the country in the Boreal zone.

These results illustrate more choices than shown in previous tables. What is of interest are the relative magnitudes involved and the resultant distribution within and among political and ecological regions. Note also the differences between Tables 5 and 10. In Table 10, research on coniferous sawlogs and veneer logs in Central Canada's 8.3 region has the highest magnitude of benefits and ranks first in relativity. In Table 5, pulpwood and coniferous sawlogs and veneer logs in Western Canada ranked first because of the magnitude of production occurring in the different production environments. Most of Central Canada's coniferous sawlogs and veneer logs production occurs in Zone 8.3. Western Canada also has a more heterogeneous set of production environments. In the relativity rankings of Table 10, zero values mean there is no production of that commodity in that ecological zone in that region. Research in these climatic zones is therefore likely to have little or no economic impact within these regions.

This type of analysis illustrates one approach to articulating a wider set of research choices relevant to decision makers. Decisions are clearly being made that do focus research efforts on different production environments.

5. CONCLUDING REMARKS

The previous section outlined several types of results of the application of an international trade model that estimates the potential benefits of a *standard* research impact. It was demonstrated that different research objectives can change both the magnitude and distribution of welfare gains to society. While this is intuitively obvious, the framework and information system illustrate a *systematic* approach to investigating and quantifying the *relative* magnitude of these potential outcomes.

Are the results, and the process of generating results, of use to decision makers in Canada? For some, it will likely reinforce their own judgments; for others, it may challenge their views; and, for some, it will stimulate their thoughts on priority setting. Earlier tables illustrate some of the choices that decision makers implicitly face. Explicit systematic consideration of the variables included in this framework does not occur during current priority-setting exercises. The intent of an information system such as this would be to support explicit consideration of these variables and to focus research priority debates in terms of objectives, type of research emphasized, and in which production environments.

There are, of course, potential costs to adopting this type of information system. Resources and education are required to institutionalize the thought processes and model development. Some decision makers may not want to be explicit about the subjective information included in the information generation phase. Some may not perceive that it will improve the decision-making process. Others will see it as an opportunity to make the priority-setting process more open, systematic, and explicit.

A number of refinements are possible that could make this type of information system more relevant to Canadian forestry research managers. These include:

Refining Production Environment/ Ecoregion Definition

The production environment classification system should be more closely linked to ecological zones familiar to Canadian decision makers. Each province may have a preferred production environment classification (e.g.,

Table 9. International benefits by province – relativities.

Newfoundland		Prince Edward Island		Nova Scotia		New Brunswick	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (NC)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0
Sawlogs & veneer logs (NC)	4.6	Sawlogs & veneer logs (NC)	4.6	Pulpwood	4.5	Pulpwood	3.9
Pulpwood	4.8	Pulpwood	4.8	Sawlogs & veneer logs (NC)	4.7	Sawlogs & veneer logs (NC)	6.7
Fuelwood (NC)	6.5	Fuelwood (NC)	6.4	Fuelwood (NC)	6.5	Fuelwood (NC)	8.1
Other ind. roundwood	7.6	Other ind. roundwood	7.6	Other ind. roundwood	7.7	Fuelwood (C)	8.6
Fuelwood (C)	10.4	Fuelwood (C)	10.7	Fuelwood (C)	10.8	Other ind. roundwood	8.9
Regional relativities	1.8		1.8		1.7		1.0

Quebec		Ontario		Manitoba		Saskatchewan	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C)	1.0
Pulpwood	4.9	Pulpwood	3.9	Sawlogs & veneer logs (NC)	4.5	Sawlogs & veneer logs (NC)	3.7
Sawlogs & veneer logs (NC)	5.3	Sawlogs & veneer logs (NC)	4.4	Fuelwood (NC)	4.9	Fuelwood (NC)	4.2
Fuelwood (NC)	6.1	Fuelwood (NC)	5.3	Pulpwood	5.3	Fuelwood (C)	4.9
Other ind. roundwood	9.5	Other ind. roundwood	7.9	Other ind. roundwood	6.1	Pulpwood	5.7
Fuelwood (C)	9.7	Fuelwood (C)	8.4	Fuelwood (C)	6.7	Other ind. roundwood	6.9
Regional relativities	1.0		1.1		1.3		1.6

Alberta		British Columbia		Yukon/Northwest Territories	
Commodity ranking	Relative benefits	Commodity ranking	Relative benefits	Commodity ranking	Relative benefits
Sawlogs & veneer logs (C)	1.0	Sawlogs & veneer logs (C) and pulpwood	1.0	Sawlogs & veneer logs (C)	1.0
Sawlogs & veneer logs (NC)	4.9	Sawlogs & veneer logs (NC)	6.4	Fuelwood (NC)	5.8
Fuelwood (NC)	6.2	Fuelwood (NC)	8.6	Fuelwood (C)	7.4
Pulpwood	6.3	Other ind. roundwood	9.9	Other ind. roundwood	10.6
Fuelwood (C)	7.9	Fuelwood (C)	0.0	Pulpwood	0.0
Other ind. roundwood	8.7			Sawlogs & veneer logs (NC)	0.0
Regional relativities	1.4		1.4		1.3

Table 10a. Regional benefits with alternative research foci[a].

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C) 8.3	26	Sawlogs & veneer logs (C) 8.3	254	Sawlogs & veneer logs (C) 9.3	35	Sawlogs & veneer logs (C) & pulpwood 10.1	209
Pulpwood 8.3	23	Pulpwood 8.3	85	Sawlogs & veneer logs (C) 8.3	21	Sawlogs & veneer logs (C) & pulpwood 7.7	176
Pulpwood 7.7	14	Sawlogs & veneer logs (C) 9.3	77	Sawlogs & veneer logs (C) 10.1	20	Sawlogs & veneer logs (C) & pulpwood 9.3	76
Sawlogs & veneer logs (C) 7.7	10	Sawlogs & veneer logs (NC) 8.3	43	Pulpwood 10.1	8	Sawlogs & veneer logs (C) & pulpwood 8.3	49
Sawlogs & veneer logs (C) 9.3	8	Sawlogs & veneer logs (C) 10.1	38	Pulpwood 9.3	6	Sawlogs & veneer logs (NC) 7.7	1
Pulpwood 9.3	7	Pulpwood 10.1	29	Sawlogs & veneer logs (NC) 9.3	4	Sawlogs & veneer logs (NC) 10.1	0
Sawlogs & veneer logs (NC) 7.7	2	Pulpwood 9.3	25	Pulpwood 8.3	3	Sawlogs & Veneer logs (NC) 8.3	0
Pulpwood 10.1	1	Sawlogs & veneer logs (NC) 9.3	13	Sawlogs & veneer logs (NC) 8.3	2	Sawlogs & veneer logs (NC) 9.3	0
Sawlogs & veneer logs (NC) 8.3	1	Sawlogs & veneer logs (C) 7.7	0	Sawlogs & veneer logs (NC) 10.1	1		
Sawlogs & veneer logs (NC) 9.3	0	Sawlogs & veneer logs (NC) 10.1	0	Pulpwood 7.7	0		
Sawlogs & veneer logs (C) 10.1	0	Sawlogs & veneer logs (NC) 7.7	0	Sawlogs & veneer logs (C) 7.7	0		
Sawlogs & veneer logs (NC) 10.1	0	Pulpwood 7.7	0	Sawlogs & veneer logs (NC) 7.7	0		

Table 10b. Regional benefits with alternative research foci – relativities.

Eastern Canada		Central Canada		Prairies Canada		Western Canada	
Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits	Commodity ranking	Regional benefits
Sawlogs & veneer logs (C) 8.3	1.0	Sawlogs & veneer logs (C) 8.3	1.0	Sawlogs & veneer logs (C) 9.3	1.0	Sawlogs & veneer logs (C) & pulpwood 10.1	1.0
Pulpwood 8.3	1.2	Pulpwood 8.3	3.0	Sawlogs & veneer logs (C) 8.3	1.6	Sawlogs & veneer logs (C) & pulpwood 7.7	1.2
Pulpwood 7.7	1.8	Sawlogs & veneer logs (C) 9.3	3.3	Sawlogs & veneer logs (C) 10.1	1.7	Sawlogs & veneer logs (C) & pulpwood 9.3	2.8
Sawlogs & veneer logs (C) 7.7	2.6	Sawlogs & veneer logs (NC) 8.3	6.0	Pulpwood 10.1	4.4	Sawlogs & veneer logs (C) & pulpwood 8.3	4.3
Sawlogs & veneer logs (C) 9.3	3.4	Sawlogs & veneer logs (C) 10.1	6.8	Pulpwood 9.3	6.4	Sawlogs & veneer logs (NC) 7.7	149.3
Pulpwood 9.3	3.9	Pulpwood 10.1	8.9	Sawlogs & veneer logs (NC) 9.3	8.8	Sawlogs & veneer logs (NC) 10.1	696.7
Sawlogs & veneer logs (NC) 7.7	13.8	Pulpwood 9.3	10.0	Pulpwood 8.3	11.3	Sawlogs & veneer logs (NC) 8.3	0.0
Pulpwood 10.1	43.7	Sawlogs & veneer logs (NC) 9.3	19.9	Sawlogs & veneer logs (NC) 8.3	19.5	Sawlogs & veneer logs (NC) 9.3	0.0
Sawlogs & veneer logs (NC) 8.3	52.4	Sawlogs & veneer logs (C) 7.7	635.8	Sawlogs & veneer logs (NC) 10.1	70.2		
Sawlogs & veneer logs (NC) 9.3	262.0	Sawlogs & veneer logs (NC) 10.1	0.0	Pulpwood 7.7	0.0		
Sawlogs & veneer logs (C) 10.1	0.0	Sawlogs & veneer logs (NC) 7.7	0.0	Sawlogs & veneer logs (C) 7.7	0.0		
Sawlogs & veneer logs (NC) 10.1	0.0	Pulpwood 7.7	0.0	Sawlogs & veneer logs (NC) 7.7	0.0		
Regional relativities	9.8		1.0		7.3		

[a]Alternative research foci refers to research occurring in particular climatic zones (see text for explanation).

Rowe's [1972] forest regions, B.C's biogeoclimatic zones, Ontario's site regions). Incorporating this modification for a Canada or province-only analysis would be straightforward. Derivation of national or international spillover benefits would be more problematic, as these regions would need to be related to the rest of the world's production environments.

Focusing on Species Versus Commodities

It is possible to focus on a more disaggregated set of wood commodities that would be more relevant to Canadian decision makers. Using the production of species or aggregate species groupings may be more relevant and produce a wider range of choices for research within regions. There are, however, trade-offs; international and national spillovers would likely be more difficult to model. This approach requires additional investigation.

Consideration of Non-wood Goods and Services

An important component of this type of approach is to relate research to commodities or outputs that can be described in economic terms. The forest "commodities" in the model thus far deal only with wood outputs from forests. While wood values continue to be an important focus for research, environmental and other non-wood values (e.g., recreation demand) are increasingly important for Canadian forestry research decision makers. The issue of relative research priorities for non-wood forest outputs is more difficult; however, notions of demand and supply can, in principle, be related to nonmarketed goods and services. The obvious challenge is applying some empirical analysis to this conceptualization. Quantifying the relative production levels of some important non-wood values for which research is distinctly separate could be one approach. This would aid in quantifying these notions and also allow decision makers to systematically explore the implications of varying assumptions. The issue clearly requires additional research at this stage.

Focus on Research Areas/Disciplines

Another approach to match more closely the information generated to decision makers' choices would be to couple the commodity choices to particular disciplines or research areas. The Forest Research Advisory Council of Canada annually identifies a number of priority areas for research. (The 1991 priorities were listed in Section 2.) To incorporate this type of subject area list into the research evaluation framework would require specifying differing lags, spillovers, and relative research strengths to each topic area. One approach would be to develop a consensus-based approach for decision makers to specify these estimates (e.g., Delphi surveys).

The process of developing a useful information system to support research priority setting is very much a research exercise in itself. Decision makers will need to be convinced of its value in assisting them. Several points about this system should be kept in mind:

- The framework is based on the received literature on the economics of research and research evaluation. It is explicit, systematic, and repeatable.
- The framework is a potentially *rich* source of information from national, regional, and provincial perspectives.
- The framework collapses into useful summaries, the myriad of data and subjective information that are the major factors influencing the generation of welfare gains due to research.

ACKNOWLEDGMENTS

The authors acknowledge the useful comments of P. Hall, R. Jacques, R. Smith, and R. Bouchier. We also acknowledge the CFS Science and Technology Opportunities Fund for contributing to this study.

LITERATURE CITED

Bullard, S.H. 1986. Potential reasons for publicly funded forestry research as reflected in the U.S.A. experience. For. Ecol. Manage. 17:53–59.

Davis, J.S. 1991. Spillover effects of agricultural research: importance for research policy and incorporation in research evaluation models. Aust. Cent. Int. Agric. Res./Int. Serv. Nat. Agric. Res. Canberra, Australia. ACIAR/ISNAR Proj. Paper 31.

Davis, J.S.; Bantilan, M.C.; Ryan, J.G. 1994. Development of information systems 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. Monogr. 17.

Davis, J.S.; Fearn, M. 1992. Information to support resource allocation for forestry research: aggregate priorities and project level assessments. Paper prepared for ACIAR Forestry Program Project Leaders Meeting, Feb. 1992. Aust. Cent. Int. Agric. Res., Canberra, Australia.

Davis, J.S.; McKenney, D.W.; Turnbull, J.W. 1989. Potential gains from forestry research and a comparison with agricultural commodities: a preliminary assessment. Aust. Cent. Int. Agric. Res./Int. Serv. Nat. Agric. Res. Canberra, Australia. ACIAR/ISNAR Proj. Paper 15.

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

Davis, J.S.; Oram, P.A.; Ryan, J.G. 1987. Assessment of agricultural research priorities: an international perspective. Aust. Cent. Int. Agric. Res./Int. Serv. Nat. Agric. Res. Canberra, Australia. Monogr. 4.

Davis, J.S.; Ryan, J.G. 1987. Institutionalisation of agricultural research priority assessment: an application. Aust. Cent. Int. Agric. Res./Int. Serv. Nat. Agric. Res. Canberra, Australia. ACIAR/ISNAR Proj. Paper 5.

Davis, J.S.; Ryan, J.G. 1994. 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. Monogr. 17.

Food and Agriculture Organization (FAO). 1983. Yearbook of forest products. Rome, Italy.

Food and Agriculture Organization (FAO). 1985. Forest product prices. Rome, Italy. FAO Paper 61.

Forest Research Advisory Council of Canada. 1992. Forest research priorities in Canada, 1991. For. Chron. 68: 121–125.

Fox, G. 1986. A framework for identifying public research priorities: an application in forestry research. U.S. Dep. Agric. For. Serv., North Cent. For. Exp. Station, St. Paul, Minnesota. General Tech. Rep. NC–109.

Huang, Y.S.; Teeter, L. 1990. An economic evaluation of research on herbaceous weed control in southern pine plantations. For. Sci. 36:313–329.

Hyde, W.F.; Newman, D.H.; Seldon, B.J. 1992. The economic benefits of forestry research. Iowa State University Press, Ames, Iowa.

McKenney, D.W.; Davis, J.; Turnbull, J.W.; Searle, S.D. 1993. The impact of Australian tree species selection research in China: an economic perspective. For. Ecol. Manage. 60:59–76.

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

Mellor, J.W. 1987. Links between technology, agricultural development, economic growth and trade creation. *In* J.G. Ryan, ed. Building on success: agricultural research, technology, and policy for development. Report of a symposium held at Canberra, 14 May 1987, Aust. Cent. Int. Agric. Res. Canberra, Australia. Tech. Rep. 7.

Moore, W.C.; Newstead, R.G. 1992. Evaluation of research and development accomplishments: Northern Forestry Centre. Can. J. Prog. Eval. 7(1):39–50.

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

Papadakis, J. 1975. Climates of the world and their potentialities. Buenos Aires, Argentina.

Rowe, J.S. 1972. The forest regions of Canada. Can. For. Serv., Ottawa, Ont. Publication 1300.

Statistics Canada. 1983–85. Logging industry. Statistics Can., Ottawa, Ont. Catalogue No. 25–201, various issues.

Vertinsky, I.V.; Wehrung, D.V.; Brumell, S. 1991. Priorities for silvicultural investments: public, government and industry perspectives. For. Chron. 67:691–697.

APPENDIX A. Basic data, sources, and major assumptions used in the analyses.

Forest Product Prices and Unit Cost Reductions

Prices provide the basis for the potential unit cost reduction estimates due to research because prices are assumed to be a reasonable proxy for supply costs. However, this type of data is generally sparse for forestry. The FAO provides aggregate weighted world export unit values for many products (FAO, 1985). Due to the lack of better information these values were used. For this study, a standard 5% unit cost reduction was used for all commodities. Some explanation is required since FAO price categories do not exactly match the product categories identified. Pulpwood and fuelwood prices do match the FAO product classification scheme; however, prices for the other classes have to be inferred. Simplifying assumptions have been made due to data limitations. World prices were also used for the Canadian forest products. The following summarizes the assumptions made in identifying prices for some products:

- The coniferous sawlogs and veneer logs category used the coniferous log price series.
- Depending on the country location, the nonconiferous sawlogs and veneer logs category used: (a) the nonconiferous logs; (b) tropical logs–Africa; and (c) tropical logs–Asia, price series.
- The same price was used for both coniferous and nonconiferous fuelwood.
- Other industrial roundwood was assumed to have the same price as pulpwood.

The standard unit cost reductions are provided in the data tables in this appendix.

Supply and Demand Elasticities

Elasticity estimates for primary forest products are also scarce. The general lack of demand and supply elasticity estimates for the primary forest products resulted in the need to rely on intuition. There are, of course, a myriad of factors that influence both demand and supply elasticities. These include substitute products, their prices, and both private and public forest policy. It is important to note that elasticity estimates are primarily used in the model to calculate the distribution of benefits between producers and consumers within countries. These results have generally not been used to date and are not reported in this paper. The results presented here are not sensitive to the elasticity estimates.

Country Groupings

It was necessary to aggregate countries to keep the analysis manageable. For the sake of brevity, this report uses the ACIAR country groupings and disaggregates Canada to eleven regions (ten provinces and the two territories as one region). Obviously, this grouping does not preclude analysis of countries or regions that may be of specific interest to other researchers.

Estimation of Potential Research Spillover Effects for Forestry

The spillover index, S, is a product of three matrices ($\mathbf{S} = \mathbf{R}\,\mathbf{C}\,\mathbf{F}$). **R** refers to the production environment where research is emphasized. **C** refers to the expected production environment spillovers. **F** refers to the commodity production shares for each country by production environment. Sound technical knowledge of world forestry is essential to provide estimates of the information. Detailed quantitative information is not available to estimate all of the parameters required. Subjective assessments are necessary; however, they are considered useful for decision makers to better understand the procedures.

As mentioned in the section "Illustrative Results from an International Analysis," ACIAR has adopted the agroclimatic classification developed by Papadakis (1975) for international forestry. Table A.1 provides a condensed outline of the basic agroclimatic spillover estimates used in the analysis. These correspond to matrix **C**. The diagonal elements include values 0.9 and 0.5, with 0.9 referring to the value used as the research spillovers to the same first decimal subzone. Thus, the spillover from Zone 1.1 in Country 1 to Zone 1.1 in Country 2 is 0.9. On the other hand, the spillover from Zone 1.1 in Country 1 to Zone 1.3 in Country 3 was judged to be 0.5. Each of the entries in the rest of the table represent a block submatrix of up to nine rows and nine columns.

The potential research emphasis parameters, **R**, are difficult to assess at an aggregate multi-country level. For this analysis it was assumed that the research emphasis for each zone within each country was the same as the proportion of output produced in that zone for the commodity concerned (i.e., $\mathbf{R}=\mathbf{F}'$). This assumption was changed in Section 4.

Data on forestry product production shares (**F**) for each agroclimatic zone were not available. These shares were therefore determined using subjective assessments

Table A.1 Production environment spillover estimates ('C' matrix).

Production environment where research is focused	Production environment where research has impact																			
	1.3	1.4	1.5	2.2	3.2	3.7	4.2	4.3	4.7	5.4	6.2	6.5	6.8	7.1	7.3	9.3	9.5	9.7	9.8	10.1
1.3	1.0	0.5	0.5	0.3			0.3	0.3	0.3											
1.4	0.5	1.0	0.5	0.3			0.3	0.3	0.3											
1.5	0.5	0.5	1.0	0.3			0.3	0.3	0.3											
2.2	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	0.3	0.3										
3.2				0.3	1.0	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
3.7				0.3	0.5	1.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3							
4.2	0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.5	0.5	0.3										
4.3	0.3	0.3	0.3	0.3	0.3	0.3	0.5	1.0	0.5	0.3										
4.7	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	1.0	0.3										
5.3				0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.3	0.3	0.3	0.3	0.3					
5.4				0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.3	0.3	0.3	0.3	0.3					
6.2					0.3	0.3				0.3	1.0	0.5	0.5	0.3	0.3					
6.5					0.3	0.3				0.3	0.5	1.0	0.5	0.3	0.3					
6.8					0.3	0.3				0.3	0.5	0.5	1.0	0.3	0.3					
7.1										0.3	0.3	0.3	0.3	1.0	0.5					
7.3										0.3	0.3	0.3	0.3	0.5	1.0					
9.3																1.0	0.5	0.5	0.5	
9.5																0.5	1.0	0.5	0.5	
9.7																0.5	0.5	1.0	0.5	
9.8																0.5	0.5	0.5	1.0	
10.1																				1.0

Source: Estimated by Dr. J. Turnbull, ACIAR Forestry Program Coordinator in consultation with other forestry experts.

by forest researchers of production distributions for each country. Again, for the sake of brevity and illustration, this paper uses the base ACIAR assumptions for the Canadian analyses. However, estimates of the production proportion shares of the commodities within the provinces were done in consultation with Dr. Paul Addison, Canadian Forest Service–Ontario.

Relative Research Strengths and Ceiling Level of Adoption

The relative chance of forestry research being successful in each country/region was subjectively assessed using knowledge of the strength of national research systems and, therefore, their likely ability to complete forestry research projects successfully. It was felt that researchers could work across all forestry products. Therefore, the same estimates were appropriate for all eight products.

Ceiling levels of research adoption were felt to differ between two groups of forestry products. In many countries, fuelwood is grown either as natural forest or in relatively small areas, rather than in large-scale public forests. With weaker forest extension services and limited availability of other infrastructure, education, facilities, etc., it was felt that ceiling adoption levels would be lower for these products. For the remaining products: pulpwood, saw and veneer logs, and other industrial roundwood, larger-scale production is more likely concentrated in industrial or publicly owned forests and adoption levels were therefore judged to be higher.

The strength of Canada's national forestry research system and potential ceiling levels of adoption were assumed to be the same as other major developed countries.

Lags and Discount Rate

The lags in research and adoption used in Davis *et al.* (1987) were 11 years in the country undertaking the research and 15 years for those receiving spillover benefits. For forestry, this type of lag structure was felt to be applicable for some products and types of research. However, there is clearly some uncertainty about the applicability of these lags. Lags of 30–50 years or more are often suggested for some types of research. Nevertheless, for the results presented in this paper, the same lag for all products is used. Future efforts and reports will investigate the importance of this assumption on relative rankings.

The discount rate used is 8% unless otherwise indicated. Because this is a real rate, it is higher than sometimes used in forestry benefit cost analyses. On the other hand, because most agricultural research evaluation studies show internal rates of return greater than this, it may be viewed as an appropriate opportunity cost of public research funds. Regardless, as long as research costs are assumed to be similar and lags the same, only absolute values will be affected by this assumption, not the relativities, which are often of primary interest to decision makers. Once lags and other parameters are allowed to vary between commodities, choice of this parameter takes on increased importance.

Summary

To summarize, a range of data (actual or estimates) is required to generate results: product definition, production and consumption levels, prices, elasticities, potential research spillovers among similar ecological regions, assessments of relative strengths of research systems, the potential adoption levels for the research outputs, research lags, adoption lags, and a discount rate. An important assumption in the base applications is that research on all commodities results in a standard 5% reduction in the cost of producing a unit of the commodity. Estimates of the subjective data are obtained through consultations and consensus of research managers and technical experts. It is worth emphasizing again that results are part of a systematic process. Uncertainty about the input values can be accommodated via sensitivity analysis.

The databases and output are in computer spreadsheet form. The research evaluation trade model is a FORTRAN program called RE5 and runs on an IBM or compatible personal computer.