



United States
Department of
Agriculture

Forest Service

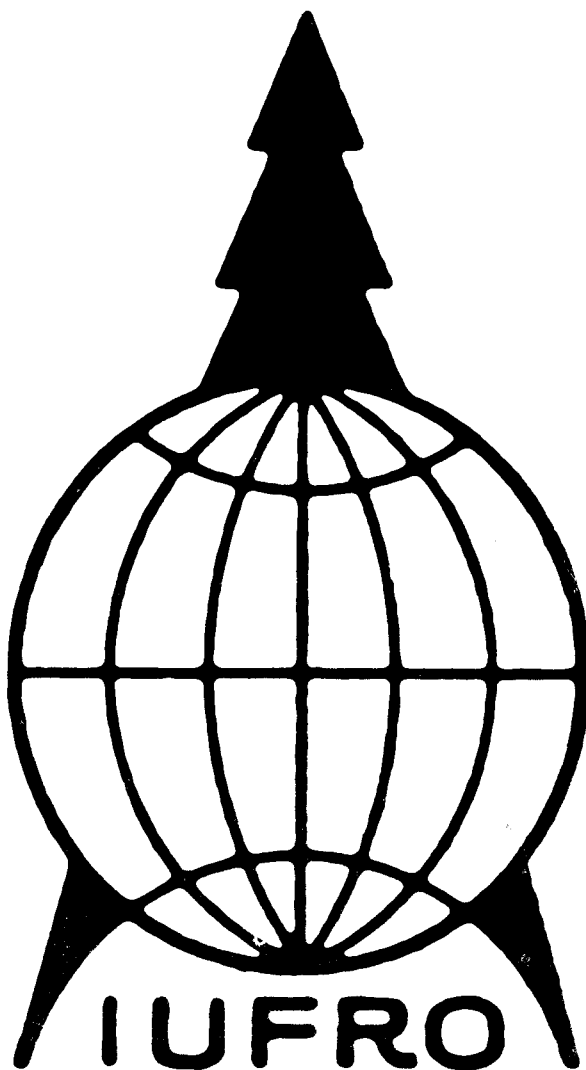
**Northeastern Forest
Experiment Station**

General Technical
Report NE-157



Research Management for the Future

International Union of Forest Research
Organizations Working Party S6.06/6.08



XIX World Congress
Montreal, Quebec, Canada
August 5-11, 1990

Preface

On August 7-9, 1990, Subject Group S6.06/6.08 (RESEARCH MANAGEMENT) of the International Union of Forestry Research Organizations (IUFRO), held a meeting as part of the XIX Congress of the International Union of Forestry Research Organizations, in Montreal, Canada. The theme of the joint S6.06/6.08 meetings was "Research Management for the Future." In order to give the papers presented the wider audience they deserve, they are being published here as a proceedings of that meeting.

Papers were presented in two different discussion sessions, as shown on the program for the meeting in the Appendix. Here they are presented sequentially, in the order shown on the program.

A list of those who attended the meeting will be found in the Appendix.

Denver P. Burns, Leader
S6.06/6.08

Each contributor submitted camera-ready copy and is responsible for the accuracy and style of his or her paper. The statements of contributors from outside the U.S. Department of Agriculture may not necessarily reflect the policy of the Department.

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November 1991

Research Management for the Future

PROCEEDINGS OF A MEETING OF

IUFRO SUBJECT GROUPS S6.06/6.08, MANAGEMENT OF FORESTRY RESEARCH
IN CONJUNCTION WITH THE XIX CONGRESS OF THE
INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

AUGUST 7-9, 1990
MONTREAL, CANADA

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Introduction

Denver P. Burns
Leader, IUFRO Subject Group S6.06/6.08

A striking phenomenon has been occurring in the United States of America and it is related to the purposes of S6.06/6.08. During the past three decades the United States has moved from an attitude that there was enough forest land for all uses, to a position where all land has been allocated to some form of resource management. Once this shift occurred, it was soon apparent that traditional ways of managing and investing in forest resources were no longer sufficient to provide the goods and services the public needed and demanded from the forests. Without the option of expanding operations to unmanaged forest land, the resource managers are turning to forestry research to provide new technology, better information and, in general, a way out of the dilemma of ever greater demands on a finite land base.

Through the efforts of the International Union of Forestry Research Organizations, and many other groups, we can see the global community turning to the research community for answers, just as is occurring in the United States. The problems take many different forms but the recurring theme is that research may provide the only way out of the dilemmas faced by many countries and indeed the global community.

Research leaders have always asserted that research could provide information and tools to solve more forestry problems if only the research community was given some visibility, encouragement, and support. Now, new attention is being focused on the forestry research community, and it is apparent that traditional research organizations and methods may not be adequate to address the major issues. Even more complex is the fact that many countries lack a viable research organization. So, the next few decades promise to be an exciting and creative time for forestry research administrators. By working together, and sharing ideas and experiences, we have unlimited opportunities to better our world.

During the past seven years, Section 6.06/6.08 - The Management of Forestry Research, has worked to address forestry research management issues through a series of international meetings, and the publication of key proceedings to serve as an information source for current and future research managers. The papers presented here report on tests of some new approaches to research management.

The publication before you is the third published Proceedings of S6.06 meetings. Prior publications were of the 1985 meeting in Ft. Collins, Colorado, USA, and the 1989 meeting at Alice Holt Lodge, Farnham, England.

The North American Sugar Maple Decline Project: Planning, Organization and Implementation

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Introduction

In January of 1987, approximately 35 scientists representing the United States and Canada met in Burlington, Vermont to review the status of sugar maple decline. A number of different Federal agencies from each government were represented as were both State and Provincial organizations. All were concerned about the health of sugar maple and whether or not acidic deposition (acid rain) was involved.

As Program Manager of the Eastern Hardwoods Research Cooperative, a research program located at the Northeastern Forest Experiment Station and designed to determine if acid rain was affecting eastern hardwood forests, I was concerned about the adverse publicity related to acid rain and sugar maple and organized the meeting. The purpose of the meeting was to see if there was interest on the part of those attending in developing a joint research effort between the United States and Canada. to see what could be done to learn more about what was causing the decline in sugar maple.

During the two days of the meeting discussions about the problem and how it should be approached were open, candid, and sometimes heated. Sampling methodologies to measure change in trees were considered, discussed, and often rejected because of difficulty in obtaining measurements, inconsistency, or cost. Considerable concern was expressed about whether or not commercial sugar bush operations should be included or if it would be better to limit the study to naturally growing stands of sugar maple. Some participants were concerned about the extent of the study and felt it should be limited to Quebec and Vermont; others felt the study should represent the entire range of sugar maple.

As each topic was discussed and resolved the participants concentrated more and more on development of a goal statement and a set of objectives for the joint study. All present realized that it would be a better and much more comprehensive study if the two governments and the states and provinces cooperated. This then was the genesis of the North American Sugar Maple Decline Project or NAMP as it came to be known.

Mission and Objectives

The North American Sugar Maple Decline Project is an international effort between Canada and the United States to assess if and where decline of sugar maple is occurring. The objectives of the project are to:

1. Determine the rate of change in maple tree condition ratings from 1988 through 1990 (both the USDA Forest Service and Forestry Canada have agreed to extend the time period for at least two more years).
2. Determine if the rate of change in sugar maple tree condition is different between a) various levels of acidic deposition; b) sugarbush vs undisturbed forest stands; and c) various levels of initial stand decline condition.
3. Determine the possible causes of sugar maple decline and geographical relationship between causes and extent of decline.

A research strategy was conceived to achieve these objectives and consisted of three phases. Phase I occurred during the period January through September, 1987 and emphasized refinement of the planning document and the design and testing of field protocols for collecting data. Phase II occurred during the summer of 1988 and concentrated on field plot establishment and taking the first tree vigor ratings. Phase II also included plans for remeasurement of tree condition during the summer of 1989. Phase III provided for intensive sampling of stands if abnormal conditions were observed in Phase II. In essence, Phases I and II were directed at an extensive sampling program to detect change in tree condition over a two year period and Phase III would provide for a more intensive research effort to determine cause, if change was observed in Phases I and II.

Project Organization

The organizational chart for the Project is shown in Figure 1. The Project was administered by a Joint Management Team consisting of Dr. L. Carlson, Forestry Canada, and Dr. M.W. McFadden, USDA Forest Service, Co-chairmen. As indicated, the Project was administered under a Memorandum of Understanding between the United States and Canada. A Technical Core Committee consisting of scientists from both the U.S. and Canada developed the workplan and the National Coordinators for the U.S. and Canada prepared the Field Survey Manual and coordinated data collection. A specialist in Quality Assurance/Quality Control was provided through the Eastern Hardwoods Research Cooperative and assisted the Project in training, consistency, and data management. A data management group was formed to manage data for the entire project including data storage, data manipulation, analysis and summarization.

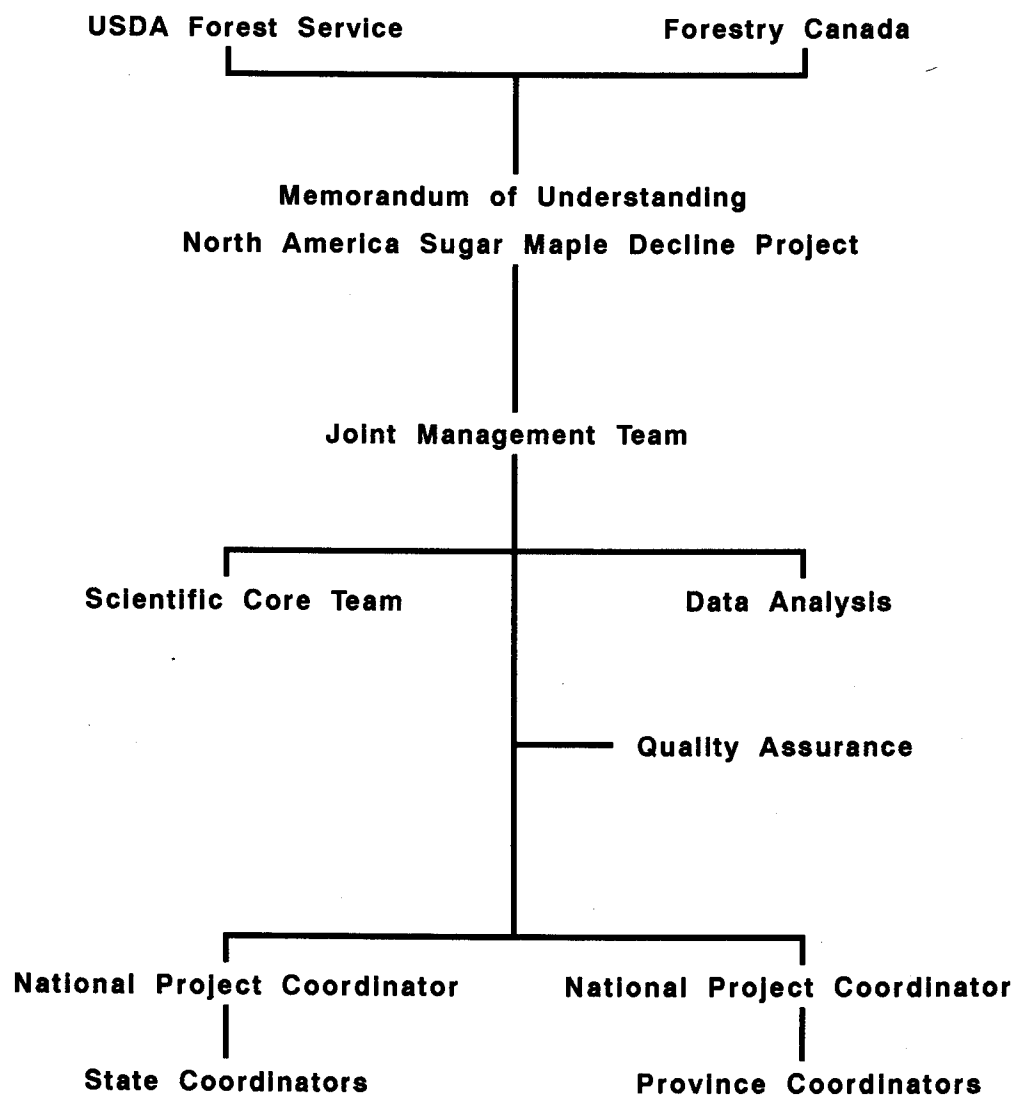


Figure 1. Organizational Chart of the North America Sugar Maple Decline Project

Project Cooperators

Although there was good geographical representation at the original meeting, it turned out that in order to have the entire range of sugar maple represented it was necessary to involve several other states and provinces in the project. Recruitment by the two national coordinators proved to be much easier than anticipated and project membership was completed in time for the first field season. Participants included:

United States

Maine: Bureau of Forestry, Department of Conservation

Massachusetts: University of Massachusetts and Division of Natural Resources

Michigan: Michigan State University and Department of Natural Resources

New Hampshire: Division of Forests and Lands

New York: State University of New York at Syracuse and State Department of Environmental Conservation.

Vermont: Department of Forests, Parks, and Recreation.

Wisconsin: Department of Natural Resources.

Canada

New Brunswick: Department of Natural Resources and Department of Municipal Affairs and Environment.

Nova Scotia: Department of Lands and Forests.

Ontario: Ministry of Environment.

Quebec: Department of Energy and Resources

In the U.S. funds were provided directly directly to cooperators by the Eastern Hardwoods Research Cooperative after appropriate funding levels had been negotiated and recommended by the U.S. national coordinator. Funding in Canada was handled differently.

Quality Assurance

One of the real challenges to the success of the Project was the issue of quality assurance. Because the Forest Response Program (FRP) was partially funded by the Environmental Protection Agency and because the Eastern Hardwoods Research Cooperative was part of the FRP, it was mandatory that the North America Sugar Maple Decline Project have a Quality Assurance/Quality Control component. This, in effect, meant that all project procedures, methodologies, data collection, data handling and data manipulation had to be standardized on both sides of the border. More importantly, it meant that field crews would have to be trained together in order to standardize data collection and reduce inconsistencies in field observations. The Quality Assurance Program also calls for field audits and so it was necessary to make provisions for the QA/QC person to travel to Canada to audit field teams in each of the cooperating provinces. One of the ways used to check on consistency of field observations was to remeasure a sample of trees using different crews from different states and provinces. This was actually carried out each year and provided evidence of levels of consistency that no one imagined possible.

Accomplishments

Project Work Plan

During the interval between the first meeting in Burlington in January, 1987 and the first test of the protocols in the following August, the Scientific Core Team met several times to further develop the research plan and the protocols that had been proposed at the Burlington meeting. The resultant North America Sugar Maple Decline Project Work Plan provided the background, purpose, and the overall direction of the project.

Cooperative Field Manual

The Cooperative Field Manual provides detailed instructions for plot selection, establishment, and data collection. The original manual was prepared in February, 1988 and was revised in July of that year after field testing. It was considered so useful in Canada that it was translated into French in 1988 and used extensively by our French speaking colleagues. The present version of the field manual includes all clarifications and changes made through the 1990 field season. It's interesting to note that many of the procedures described in the manual have since been adopted by the USDA Forest Service in a new program to monitor forest health conditions in the northeastern states.

Sugarbush Manual

During the initial meeting in Burlington sugar maple decline and other pathologies and problems affecting sugar maple were discussed extensively. Unfortunately, much of this information was inside the heads of these scientists or widely scattered in scientific journals or other printed material. As Program Manager of the Eastern Hardwoods Research Cooperative, I asked one of the scientists at the meeting to consider preparing a publication that would concentrate all of this information in a single publication. He subsequently enlisted the help of two colleagues, one from the U.S., the other from Canada to help assemble this information in a comprehensive manual. The target audience would be the managers of commercial sugar bushes. The manual was completed in August, 1990 and simultaneous press releases in the U.S. and Canada announced its availability in both English and French. In fact, news of the availability of the French version in Canada was first announced by me during this presentation.

Conclusion

There are two other papers in this proceedings that describe the North America Sugar Maple Decline Project. The paper by Burkman looks at the project from a Quality Assurance/Quality Control point of view. The paper by Allen reviews the technical aspects of the project including experimental design, plot characteristics, data collection, data base management, data handling, and results. In general, results have shown essentially no change from the original conditions measured in 1988. As a result of this, the project has not had to move into Phase III. Both the U.S. and Canada have agreed to continue the North America Sugar Maple Decline Project and will continue to gather data over the next few years as Phase II describes unless a change in rate of decline is detected.

What remains to be said in this presentation is that the North America Sugar Maple Decline Project is one of the best examples of a collaborative forestry research network in existence. A common problem was perceived, a joint plan of action was developed and a group of dedicated scientists were committed to it. A network organization was established to minimize constraints to this international research effort and to maximize research productivity. Within a very short time the international border effectively ceased to exist and vehicles, equipment, people, and ideas moved back and forth without impediment in spite of the fact that the Memorandum of Understanding between the two countries was not signed until 1990, three years after the project was initiated.

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NORTH AMERICAN SUGAR MAPLE DECLINE PROJECT - DATA ACQUISITION AND INTERIM RESULTS

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INTRODUCTION

Cooperative research endeavors such as the North American Sugar Maple Decline Project (NAMP) place unique demands on program management. This uniqueness stems, in part, from compromises required by all parties to agree on what constitutes appropriate response or descriptive variables, and concerns about reliable data acquisition for a project that involves many participants. The problems associated with selecting variables and implementing field protocols are not trivial when a variety of agencies and different political jurisdictions are the key players. We believe under these circumstances success requires several conditions: (a) a comprehensive methods manual that clearly defines variables and field techniques, (b) centralized data management and analysis, (c) annual meetings of all cooperators to review progress and resolve

problems, (d) a data quality assurance plan that includes standardized annual training for field crews, audits to confirm that methods are implemented appropriately, and remeasurement of key variables to assess data quality, and (e) cooperators who are dedicated to the consensus protocol. In our view, the maple project meets these requirements.

The purpose of this paper is to review field methods, briefly describe data collection and present selected interim results. More detailed information about methods can be obtained from the comprehensive field manual developed for this project (Millers and others 1991). Quality assurance techniques are presented by Burkman (this publication).

P l o t L o c a t i o n a n d E x p e r i m e n t a l D e s i g n

Seven states and four provinces currently participate in this project, which was initiated in 1988. Collectively, cooperators have installed 168 plot-clusters (Table 1) and a total of 840 plots (five per cluster). Each plot is 20 m square (400 m² or .04 hectare) and separated from adjacent plots by at least 20 m (Fig. 1). Half of the clusters were placed in stands managed for sap production (sugarbushes) and half in northern hardwood stands that were not sugarbushes. A requirement of the latter was that stands have no evidence of cutting or tapping for sap production during the previous

Table 1. Cooperators in the North American Sugar Maple Decline Project.

REGION	AGENCY	NUMBER OF PLOT-CLUSTERS
United States		
Maine	Maine Forest Service	18
Massachusetts	University of Massachusetts	10
Michigan	Michigan States University	10
New Hampshire	NH Division of Forests and Lands	6
New York	State University of NY, Syracuse	18
Vermont	VT Department of Forests, Parks and Recreation	26
Wisconsin	WI Department of Natural Resources	18
		Subtotal: 106
Canada		
New Brunswick	Forestry Canada	12
Nova Scotia	Forestry Canada	2
Ontario	Forestry Canada	24
Quebec	Forestry Canada	24
		Subtotal: 62
Total number of NAMP plot-clusters: 168		

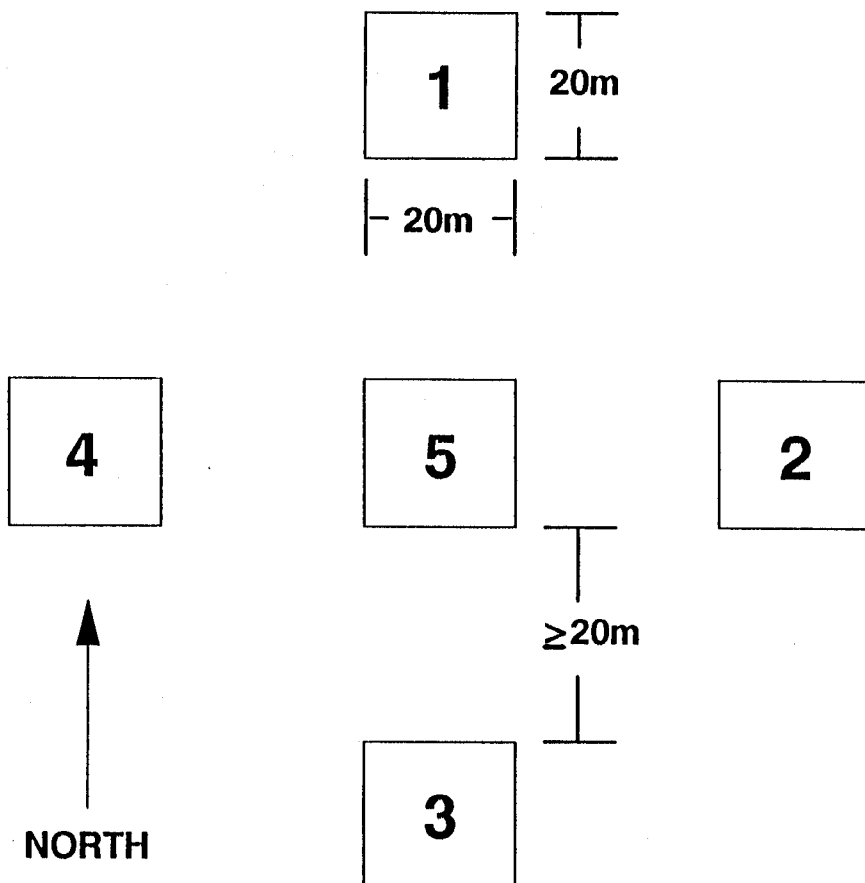


Figure 1. Plot-cluster design used by the North American Sugar Maple Decline Project. One such cluster occurs in each forest stand and sugarbush.

five years. At least 50% of the overstory trees had to be sugar maple, *Acer saccharum* Marsh, 50 to 150 years old. An attempt was made to pair stands by locating a non-sugarbush cluster within a few kilometers of each sugarbush cluster.

The number of plot-clusters established in each state or province was determined by the funds and time available to each cooperator. Plots were located so as to encompass a range of wet sulfate (SO_4^-) and nitrate (NO_3) deposition levels. Regional levels were estimated from a deposition map provided by the U.S. Environmental Protection Agency (Olsen and Engel 1987). A range of levels often could not be obtained within each state or province, but project-wide, plot-clusters are in stands that include deposition extremes.

Plot-clusters were not established randomly. Therefore, results are relevant only to trees in our plots, not the maple resource in general. Our principle objective is to document changes that occur in crown condition over time. This, coupled with the need for a long-term commitment by the landowners, made systematic sampling a necessity. Also, if trees were in extremely poor condition initially, this would have precluded collection of useful data on temporal changes in crown condition.

Plot boundaries were marked clearly and permanently. Every tree ≥ 10 cm diameter at breast height (approx. 1.4 m above ground) was numbered with a metal

tag. Three categories of data were obtained for each cluster location; a site description, a stand description and tree descriptions.

Site Description

The geographic location of each cluster (stand) was described with the Universal Transverse Mercator (UTM) grid system. This technique has advantages over other commonly used reference systems, because of its simplicity and accuracy (Grubb and Eakle 1988).

Regional physiography was recorded in terms of general terrain, drainage, weather and soil series. Local physiography associated with each plot was described by land form, percent and position of slope, microrelief, elevation, exposure (aspect), rockiness, and soil texture.

Stand Description

Descriptive variables for stands containing plot-clusters included age, species composition, crown structure (i.e., single story, two storied, etc.), degree of crown closure, visual or historical evidence of disturbance (e.g., logging, grazing, tapping, defoliation, etc.), rockiness, and an assessment of the overall site quality for sugar maple.

Tree Description

All trees in each plot were evaluated for size (diameter at breast height - DBH), crown position, and bole quality (growth impairing defects or injuries). Response variables were extent of crown dieback (% of total crown volume), crown transparency (% = a measure of crown fullness), foliage discoloration, leaf dwarfing, and current level of insect defoliation (assessed a minimum of twice each growing season). The percentage classes used to classify these crown variables and acceptable ranges of errors are summarized in Table 2.

Data Analysis

In analyses of 1988 data (first year), two critical crown measurements served as response or dependent (Y) variables; dieback and vigor. The latter is an aggregate variable that reflects, in addition to degree of dieback, the extent of foliage discoloration, leaf dwarfing, and crown transparency. A third response variable, stand relative density, was generated from the field data using equations developed by Marquis *et al.* (1984). This measure of stand density accounts for the growing space requirements (i.e., combination of all site resources) of different tree species, and stand species competition. Therefore, it is thought to be a more meaningful way to express stand density than simply relying on basal area or number of stems/ha (Stout 1987).

Table 2. Percentage classes used in the North American Sugar Maple Decline Project to rate tree crowns for dieback, transparency, leaf dwarfing, and leaf discoloration.

Percentage Class	Class Code	Class Range (%)	Acceptable Error Range
0	00	0	0 - 5
5	05	1 - 5	0 - 15
10	10	6 - 15	1 - 25
20	20	16 - 25	6 - 35
30	30	26 - 35	16 - 45
40	40	36 - 45	26 - 55
50	50	46 - 55	36 - 65
60	60	56 - 65	46 - 75
70	70	66 - 75	56 - 85
80	80	76 - 85	66 - 95
90	90	86 - 95	76 - 100
100	99	96 - 100	86 - 100

We are particularly interested in differences that might exist in current tree condition under varying stand disturbance histories, two forest management regimes (sugarbush vs undisturbed), and estimated levels of exposure to atmospheric pollutants ($\text{SO}_4^{=}$, NO_3). Updated maps of annual wet deposition were provided by Forestry Canada. These data, generated by the Canadian National Atmospheric Chemistry (NatChem) Data Base, represented 5-year (1982-86) estimates of mean wet deposition (kg/ha) by 5 kg/ha isopleths. This deposition information was more recent than that used originally to locate plot-clusters. Data points for each NAMP plot-cluster were extrapolated from the nearest isopleths and estimated to the nearest 5 kg/ha/yr. Values for $\text{SO}_4^{=}$ ranged from 10 kg/ha/yr in two Wisconsin clusters to 35 kg/ha/yr for several clusters in Michigan, New York and Ontario. Plot-clusters were placed in one of three relative deposition classes; low (10-15 kg/ha/yr), medium (20-25 kg/ha/yr) and high (30-35 kg/ha/yr). Deposition levels of NO_3 ranged from 10-20 kg/ha/yr.

During the second year of the project (1989), a new composite variable labelled Crown Condition Index (CCI) was developed to replace vigor. This index differs from the latter in that it combines dieback estimates (i.e., a measure of the extent of dead branches in the upper part of the total crown) with transparency estimates (i.e., density of foliage in that part of the crown not affected by dieback) and it excludes discoloration and dwarfing). CCI, dieback and transparency are the critical response variables

that will be used in the final analyses to assess changes in crown condition between and within plot-clusters over time.

Discussion of Preliminary Results

Mensurational data and stem and crown condition were documented in 1988 for 10,512 sugar maples and 4,065 other broadleaved trees, principally American beech (*Fagus grandifolia* Ehrh.) (7%), yellow birch (*Betula alleghaniensis* Britton (4%), red maple (*A. rubrum* L.) (4%) and ash (*Fraxinus* spp.) (3%). Sample size varied regionally from a total of 278 sugar maples in Michigan to 1,878 sugar maples in Quebec. The average diameter (DBH) of these trees ranged from $20 \pm .25$ cm in the New Brunswick-Nova Scotia clusters to $38 \pm .94$ cm in Michigan. Dominant and codominant sugar maple comprised 68% ($n = 7,099$) of the total maple sample. Stand stocking was slightly higher (range: 105-134 m² ha) and proportion of sugar maple slightly lower (44-80%) in non-sugarbushes compared to sugarbushes (91-1030 m²/ha; 60-86%). These differences are to be expected, because sugarbushes are typically monocultures of widely spaced trees.

For the purposes of this preliminary report, correlation analyses and statistical comparisons were limited to dominant and codominant sugar maples.

Seventy-one percent of the dominant/codominant sugar maples in 1988 had 5 percent or less crown dieback and 90 percent had 10 percent or less crown dieback (i.e., they were apparently healthy or had little evidence of crown loss) (Fig.2). These data comprise the baseline against which we will compare future evaluations. There was no statistically significant ($p = .05$) difference between the crown condition of maples in sugarbushes and non-sugarbushes. Only 1.6 percent ($n = 57$) of the sugarbush maples and 0.7 percent ($n = 26$) of non-sugarbush maples had crown dieback levels of 50 percent or more. Of these, 84 percent ($n = 70$) had what were judged to be growth impairing damage to the bole or major roots.

Eighteen of the 168 plot-clusters are used currently, or were used recently to graze cattle. Trees in grazed stands have little evidence of dieback and, in general, appear to have vigorous crowns.

There were no statistically significant ($p = .05$) correlations between crown condition (dieback, transparency) and wet deposition of $\text{SO}_4^{=}$ or NO_3 . Incidence of sugar maple dieback (i.e., the proportion of the sugar maples in each plot-cluster that had evidence of crown dieback) was significantly ($p \leq 0.10$) and positively correlated with stand relative density in three of four regions tested, New York ($r = 0.76$; $n = 18$), New Hampshire ($r = 0.80$; $n = 6$), and Ontario non-sugarbushes ($r = 0.52$; $n = 12$). Data from the remaining states or provinces were eliminated from the analysis, because they either experienced the confounding effects of recent insect defoliation or lacked

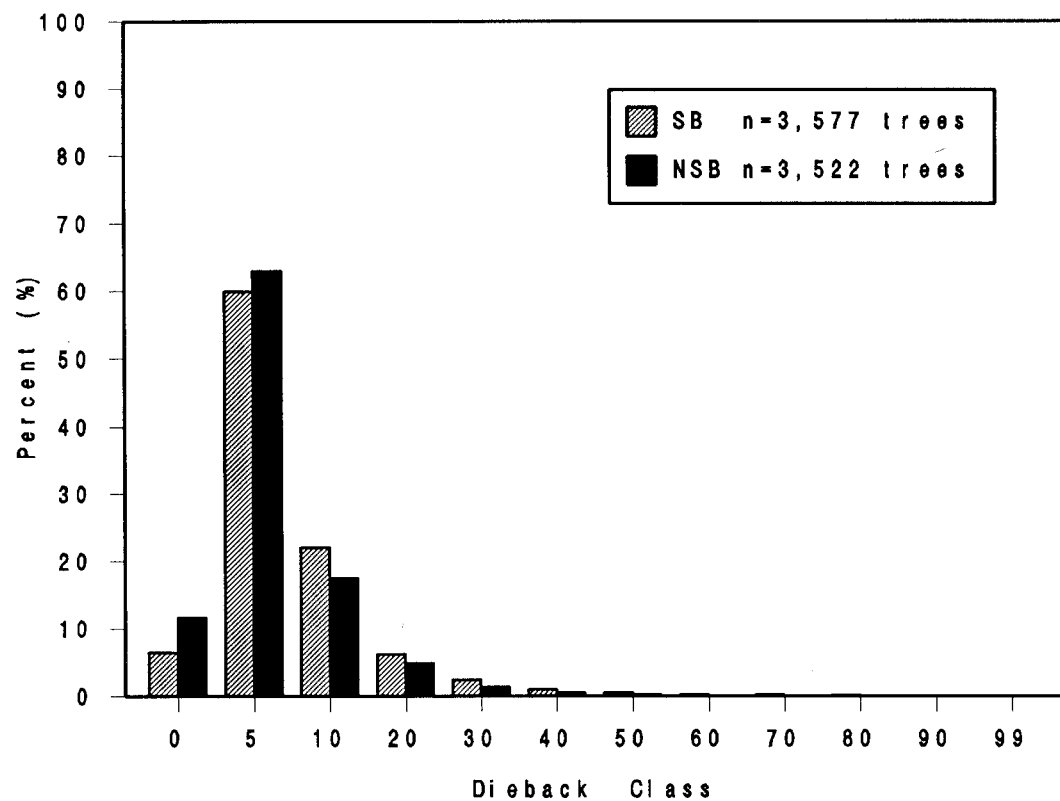


Figure 2. Frequency distribution of dominant/codominant sugar maples by dieback class (1988 data).

enough variation in dieback or relative density between plot-clusters to make an analysis meaningful.

The crown condition of dominant/codominant sugar maples in both sugarbushes and non-sugarbushes, and in low and medium deposition classes had lower crown dieback ratings in 1989 compared to 1988 (i.e., crowns apparently improved) (Fig. 3A). Trees in areas of high deposition, on the other hand, had a net increase in dieback ratings (Fig. 3B). Trees in both management categories and all deposition classes exhibited a net increase in crown transparency ratings during this same period (i.e., foliage appeared more sparse in 1989 compared to 1988) (Fig. 4). These changes from one year to the next were not statistically significant. The trends observed could be the result, in part, of special efforts during the second year of the project to improve standardization and measurement of critical crown variables, especially transparency. This was accomplished by using illustrated field guides to supplement verbal descriptions, and training. Also, the acceptable error of measurement for critical variables is ± 1 class (Millers and LaChance 1989). Ratings for approximately 80% of the sugar maples in 1989 shifted no more than 1 class compared to 1988. Therefore, these changes could be attributed to the combined effects of an actual change in crown condition, weather conditions at the time of rating (transparency estimates can vary depending on whether or not the foliage is moving at the time of measurement), or variability inherent in year-to-year changes in personnel.

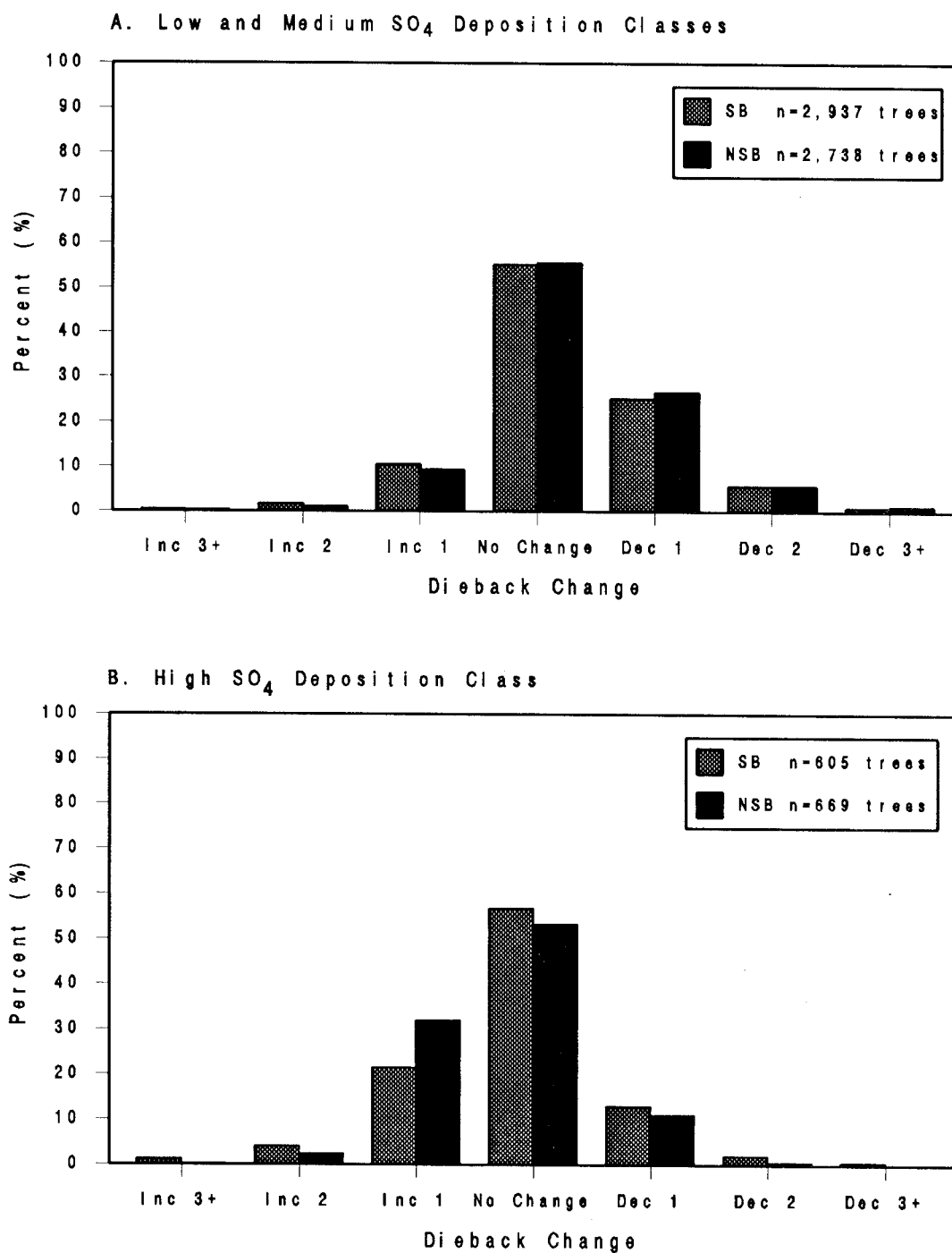


Figure 3. Change in crown dieback of dominant/codominant sugar maples located in (A) plot-clusters exposed to the low and medium classes and (B) the high class of SO₄⁼ deposition (1988 vs 1989).

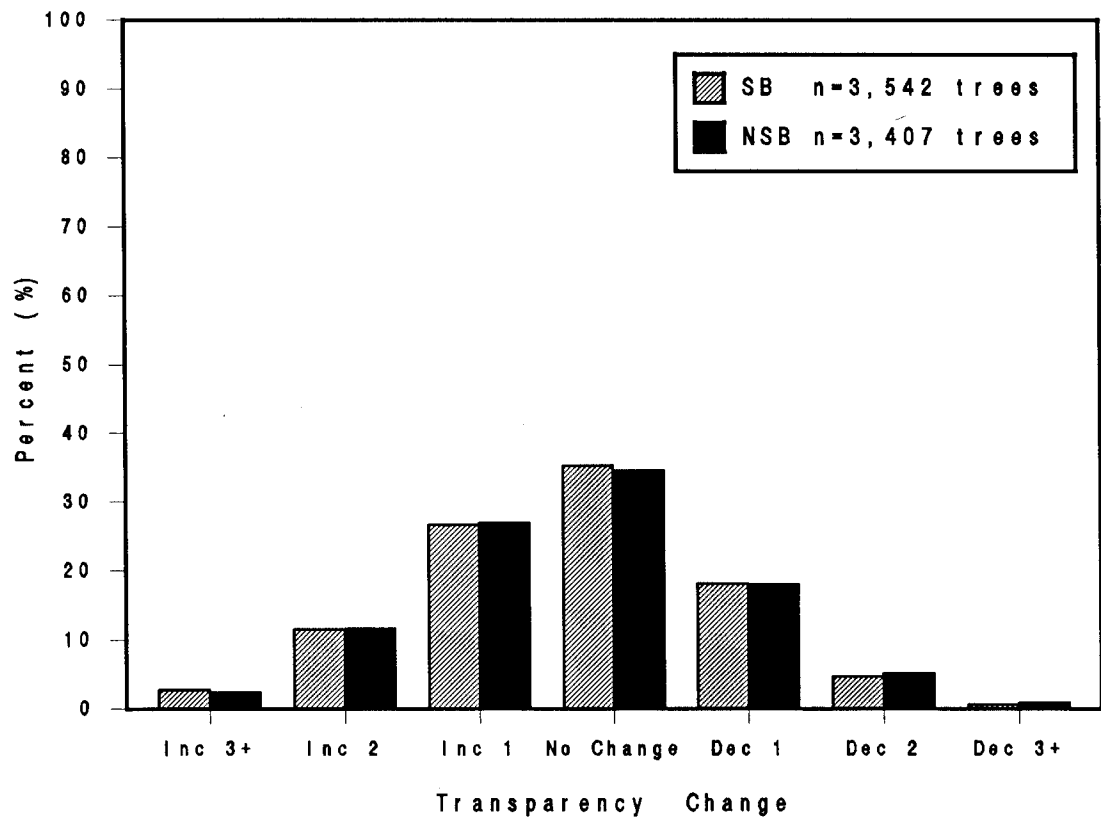


Figure 4. Change in crown transparency of dominant/codominant sugar maples (1988 vs 1989).

We believe that the value of this annual monitoring is its ability to detect major shifts in the condition of sugar maple over time. Minor changes that occur annually or over an extended period will be masked by variation intrinsic to the methods used.

T h e F u t u r e

Those of us who have been involved in NAMP are excited about this opportunity to monitor the condition of sugar maple. We believe that this endeavor must continue, however, because three years (the current funding period) is not long enough to document change. In the absence of historical documentation of disturbance history for individual trees and stands, accompanied by a description of pre-disturbance conditions, it is very difficult to interpret accurately the short- and long-term impacts of stresses placed on sugar maple, or on any tree species for that matter. In the absence of stand histories, it is tempting to speculate on cause and effect. Management recommendations based on this speculation can be misleading, if not dangerous.

In future evaluations of sugar maple health following disturbances like insect defoliation, changes in atmospheric conditions, adverse weather such as drought and late spring frost, forest management activities, or a combination of these events, we will be in a much better position to unravel causes and effects with a carefully documented and quality controlled long-term data base such as that provided by the Sugar Maple Decline Project.

SUMMARY

The success of a cooperative forest health monitoring effort that involves many agencies and jurisdictions requires a comprehensive methods manual, centralized data management, annual reviews, a data quality assurance plan, and dedicated participants. The North American Sugar Maple Decline Project monitors the health of 10,837 sugar maples and 4,285 other broad-leaved trees in seven states and four provinces. Ninety percent of 7,099 dominant/codominant sugar maples in this sample had less than 10% crown dieback in 1988. Of the 83 maples with 50% or more crown dieback, 70 (84%) had major damage to the bole or major roots. Incidence of sugar maple dieback was not associated with wet deposition of sulfate and nitrate, or cattle grazing. The crown condition of maples in sugarbushes and non-sugarbushes was similar. High levels of relative stand density was significantly correlated with incidence of maple dieback.

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Quality Assurance/Quality Control Implementation and Evaluation in the North American Sugar Maple Decline Project

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Abstract

The North American Sugar Maple Decline Project consisted of a regional survey of the condition of sugar maple (Acer saccharum Marsh.) in the United States and Canada. The major variables included four subjective measurements of tree crown conditions: branch dieback, foliage transparency, foliage discoloration, and dwarfed foliage. The implementation of formal quality assurance activities in regional forestry research has been limited. Developing the quality assurance program for this project presented some major challenges, including the participation of a large number of crews and use of subjective measures of crown condition.

To ensure the collection of the acceptable data the following quality assurance activities were implemented: 1) detailed documentation of the measurement systems; 2) a comprehensive training session for all participating crews and other project personnel; 3) use of independent audits to review field crew procedures; 4) remeasurement (quality control) of a subset of plots to assess the precision of the data; and 5) use of the remeasurement data, audit information, and training session evaluations to improve the project over time.

The effectiveness of the quality assurance program in this project is demonstrated by the overall remeasurement quality agreement, (i.e., precision) of sugar maple crown conditions for the 1988 field season: branch dieback, 95.6%; foliage transparency, 90.9%; foliage discoloration, 91.3%; and dwarfed foliage, 88.3%. The identification of methodology interpretation problems in foliage discoloration and dwarfed foliage during the 1988 audits led to an improvement in agreement percentages in 1989. All sugar maple crown condition ratings agreement percentages increased in 1989 (compared to 1988): branch dieback, +1.1% to 96.7%; foliage transparency, +0.9% to 91.8%; foliage discoloration, +7.8% to 99.1%; and dwarfed foliage, +10.5 to 98.8%. The experience acquired in this project show that quality assurance activities can be used to: 1) quantify the quality of data of subjective measurements of tree crown conditions; and 2) improve the quality of data over time.

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INTRODUCTION

Quality assurance (QA) is a planned group of activities that define the way tasks are to be performed to ensure that the final product will meet a desired level of quality. Quality assurance ensures that operations and procedures requiring control are identified and that appropriate control procedures are defined, documented, and implemented. Quality control (QC) consists of operational level activities that determine and verify the suitability of various components within a process and identify and eliminate erroneous measurements, observations, and materials, e.g. the analysis of remeasurement data.

The implementation of QA has been shown to be important in field research projects and environmental research programs (Medlarz, 1988; Cline and Burkman, 1989). Although QA programs have been implemented on an individual project basis, the use of QA in regional research programs has been limited. This application of QA will become very important as new, major monitoring programs such as the US-EPA's Environmental Monitoring Assessment Program are implemented in the United States. This report describes the implementation and evaluation of QA in a large, regional field project.

Concern about sugar maple (Acer saccharum Marsh.) condition in the United States (Millers et al., 1989) and Canada (Lachance, 1985) resulted in a cooperative agreement for a joint research project between the USDA Forest Service and Forestry Canada to investigate whether decline existed and, if so, the extent and causes of the decline. The project was funded through the Eastern Hardwoods Research Cooperative of the Forest Response Program, which operated as part of the National Acid Precipitation Assessment Project and Forestry Canada.

The objectives of the North American Sugar Maple Decline Project were to:

1. Determine the rate of change in sugar maple tree crown condition ratings from 1988 through 1990.
2. Determine if the rates of change in sugar maple tree crown condition ratings is different in:
 - a. sugarbush (used for maple syrup production) and undisturbed forested stands,
 - b. stands with various levels of initial decline conditions,
 - c. stands with varying levels of pollution measured as wet deposition.
3. If a decline is occurring, determine the possible causes and the geographical relationship between causes and extent of decline.

To accomplish the above objectives, data was collected with

the crown rating system with trees subjectively evaluated for branch dieback, foliage transparency, foliage discoloration, and dwarfed foliage. The definitions of the different tree crown measurements are:

1. Branch dieback - branch mortality that begins at the terminal portion of the branch and proceeds inward toward the trunk.
2. Foliage transparency - the amount of light visible through the foliated portion of branches.
3. Foliage discoloration - the foliated portion of the crown with leaves that are more yellow, red, or brown than green.
4. Dwarfed Foliage - the foliated portion of the crown with average leaf size less than one half the size of leaves on healthy trees nearby.

Crown condition measurements used in this study are similar to those used in European countries and Canada to monitor tree crown conditions (United Nations Economic Commission for Europe, 1988; Magasi, 1988). Tree crowns were rated using visual estimates for each crown condition rating. The same class codes were used for all four crown condition variables. Table 1 shows the percentage classes, the range of values in each class, and the acceptable range of deviation between remeasurements (for dominant and codominant trees only) for the four crown rating measurements. The 0 class was used to describe absolute zero for each particular crown condition rated.

Quality Assurance Approach

Particular concerns for developing an appropriate QA program for data comparability in this project included: 1) the use of multiple field crews, 2) the large geographic region, and 3) the use of relatively untested visual estimates of tree crown conditions. Also, because the methodology was relatively new, it was extremely important to evaluate the QA information, including QC data in the context of project goals so that project management could make improvements in methodologies for subsequent years.

To optimize the quality of data for the North American Sugar Maple Decline Project, the following aspects were addressed in project implementation:

1. The development of detailed documentation of the measurement systems, especially the crown rating measurements;
2. The use of annual training sessions for all participating crew members;

3. The use of annual, independent audits to review field crew procedures;
4. Remeasurement (QC) of a subset of plots to assess the precision of the data;
5. The use of the remeasurement data, audit information, and training session evaluations to improve the project in the following years.

These topics will be covered in the text using the North American Sugar Maple Decline Project as an example.

RESULTS

Methodology Documentation and Standardization

A workplan was developed for guidance of project personnel which included a comprehensive field manual with instructions for data collection. The project organization and methods will be published (Millers et al., in preparation). Some methods were adapted from existing published procedures, e.g. diameter at breast height (dbh). In addition, a project QA plan was developed which described all activities and was designed to ensure and quantify data quality.

Crown condition ratings were used as the measurements of tree vigor. The change in these ratings were used as a measure of decline or recovery of tree vigor. The crown condition ratings are subjective measures that required visual estimates, and visual estimations can create many interpretation problems (Innes, 1988). Standardization was the greatest concern to ensure repeatability and comparability of measurements. Repeatability was planned by the development and field testing of standard procedures, intensive training, use of training guides, and use of two persons to rate each tree. The accepted precision for the crown rating was one class deviation from the original rating. Changes in the crown condition rating greater than one class were considered significant. The project organizers set a one class deviation because precision could be affected by individual variation, different weather conditions, and minor change in tree crowns during the remeasurement period.

Additional QC practices were implemented to assist in the standardization of the crown ratings. A set of binoculars were used for closer examination of tree crowns. Each crown rating measurement was made by two persons from the opposite sides of a tree. When ratings differed, the crew personnel exchanged positions and repeated the measurements. If the individuals still did not agree on a common rating, the average from the two observers was determined and recorded. This procedure decreased the amount of individual variability.

Training

For this project, all of the personnel establishing plots, taking measurements and making crown estimates attended a one-to-two-day training session organized by the project staff. The field crew supervisors, QA auditor, and other project personnel (e.g., data management personnel) participated in the training session. The project coordinators (who also developed the procedures) conducted the training sessions. Annual retraining was required for all crew members prior to data collection.

Training was directed toward standardization of crown rating methodology, because the response measurements are subjective, (i.e., visual estimates of crown characteristics) and did not have a finite or quantitative value. Communication was encouraged so that crew personnel could ask questions about particular situations or trees. Training was continued until crews were comfortable with the methodology, usually less than 1/2 day.

The second aspect of training was performance testing. A test course of trees was set up and all project personnel individually rated the "test" trees for the four crown rating variables, from the same vantage point to reduce variability due to vantage point. After testing, a frequency distribution was developed for the variables measured on each tree using all participant results, and the distribution was used to determine the "actual" value (usually the median). Field crew personnel were evaluated and individuals with 10% of their values exceeding the allowable one class deviation (see Table 1 for exact values) were provided with additional training prior to collecting field data.

Audits

Audits were conducted yearly and the auditor attempted to visit as many crews as possible during the measurement period. The auditor accompanied the field crew on the plots and observed data collection procedures. Audit reports, qualitative summaries of audit findings, were distributed to the appropriate national coordinator (United States or Canada) and state or provincial coordinator. Through the audits, discrepancies were discovered regarding method implementation. The major problem area was individual interpretations of statements and definitions in the methods manual.

In the 1988 field season, this concern was noted for foliage discoloration and dwarfed foliage. An unexpected outbreak of pear thrips (Taeniothrips inconsequens Uzel) in southern Vermont and western Massachusetts created unusual crown conditions. In the severely defoliated areas, the trees re-foliated with a second growth flush during the late summer. In areas where the defoliation was moderate, the trees did not lose their leaves. This created crowns of tattered leaves with brown edges. The field crew was supposed to ignore these leaves for the foliage discoloration rating but to include the condition in the notes. Unfortunately, various crews interpreted this crown condition in

different ways. The situation was identified during the audits and is a good example of both the necessity and advantage of audits. Because of this problem, foliage discoloration and dwarfed foliage data were not used from 1988.

During audits, problems encountered by the crews with particular trees or situations were identified and documented. Not all potential conditions could be covered during the training sessions, so the auditor helped to reduce interpretive difficulties. Crews also were encouraged to record any concerns or problems and to convey this information to their particular state or provincial coordinator.

Remeasurement System

Data quality assessments were made to estimate the precision of the crown ratings by a remeasurement program. Remeasurements for other variables (i.e. dbh) were not taken. A minimum requirement was to remeasure at least 5% of the total plots. In 1988, 8.2% of the plots were remeasured and in 1989 it was 10.6%. The percent of the trees remeasured was 5.4% and 8.3% in 1988 and 1989, respectively. At the end of the field season the remeasurement information was compared to the original values to evaluate the measurement precision.

Remeasured values were considered the same if they were ± 1 class from the original value for dominant and codominant trees or ± 2 classes from the original for intermediate and suppressed trees. The deviation for intermediate and suppressed trees was larger because of the difficulty of eliminating shaded dead branches from branch dieback estimates, or increased background foliage influences from other trees for foliage transparency estimates. Remeasurements were also evaluated depending on the origin of the original and remeasurement crews. A portion of the remeasurements were conducted by the original crew and estimated within-crew precision. Remeasurement data collected by a different crew estimated between-crew precision. It was expected that the within-crew precision would be greater than the between-crew precision, and is supported in the analysis of the 1988 and 1989 data (not shown).

The re-foliation of crowns after pear thrips defoliation created a situation where the leaf size changed rapidly during the measurement period. Some of the crews ignored the effect of re-foliation on leaf size, but other crews included this in the dwarfed foliage measurement. The 1988 remeasurement data for dwarfed foliage (Figure 1, top) illustrates this problem. The remeasurement information from 1988 was used to improve the method and training session for the following year (Figure 1, bottom). (Note: All of the figures presented are structured in the same manner. The x-axis lists the original class code and the y-axis lists the class deviation of the remeasurement from the original. Each of the numbers represents the frequency. The solid designates no deviation and the dashed is $\pm$ one class

deviation.)

Use of Data Quality Information

After the completion of the data collection, remeasurement data was analyzed for precision estimates. This information was summarized, provided to all state and provincial coordinators, and discussed at annual project meetings. This was another communication channel in addition to auditing.

A demonstration of the success of this QA program is illustrated in Table 2, where the measurement precision are shown for 1988 and 1989. In all four crown rating categories, the precision increased in 1989 from 1988 values. Major increases were noted in foliage discoloration and dwarfed foliage measurements, + 7.8% and + 10.5%, respectively. The improved precision resulted from the elimination of the interpretative problems associated with the two crown condition variables.

The intensive crew training and testing of the crown condition measurement system resulted in 95.6% and 90.9% measurement precision in 1988 for branch dieback and foliage transparency, respectively. This information is presented for 1988 and 1989 for branch dieback and foliage transparency, (Figures 2 and 3, respectively) and shows few outliers.

The between-crew measurement precision for 1988 and 1989 is shown in Table 3. All crown rating between-crew measurement precision increased dramatically in 1989. This is most likely due to retention of crew members from 1988, improved training sessions, and improved methodology.

DISCUSSION / RECOMMENDATIONS

Methodology Documentation and Standardization

The development of detailed methodology is essential for documentation purposes. A complete method description should include materials and equipment required, procedures for each step, the performance criteria (data quality), procedures that will be used to evaluate performance criteria (remeasurements), expected data ranges, and data codes. The use of a standard manual is a key to ensuring data comparability (Garfield, 1984).

A large monitoring program may include many variables, resulting in a large methods manual. It may be necessary to develop a reduced version of the manual for everyday use. This may be a one page card or a pocket-sized manual, written in clear, concise language. The complete manual should be available to crews as a reference and for documentation of data collection procedures for future data and/or method users. The complete manual should provide the necessary documentation for the data and/or method users to determine if the procedures and/or data are appropriate for their intended use.

It is important for the manual to describe as many potential interpretations and/or situations as possible. This level of detail will increase the data comparability between individuals. During the early years of a program, the manual may need revision after each field season to clarify interpretation problems identified during the field season.

Training

Effective training is important to ensure the quality of data and comparability. In designing a training session, it is important to recognize the education and experience of the participants so the training session can be organized to address the unfamiliar procedures. Some methods may require specific types of educational backgrounds and it may be necessary to establish minimum education and/or experience standards. All project personnel including field crew supervisors, data management personnel, and program management should participate in the training session.

The site used for training should include the expected range of natural variation on the plots. Particular situations to include during the training session can be determined by understanding the expected or normal variation of the variable in the forest and/or tree species.

The training session should be structured in discrete units, possibly by variable or groups of variables. By using discrete units, the most qualified instructor can be selected to conduct training for that unit. Evaluations of personnel performance in discrete units provides immediate feedback on the effectiveness of the training. In addition, this procedure identifies individuals who may need more intensive training for particular methods, prior to actual data collection and identify problem areas in methods documentation.

A complete evaluation or test of the entire set of variables should be conducted prior to collection of actual data under simulated field conditions. Comparability among individuals can be determined if all crew personnel measure the same plots and/or trees. With a large number of individuals, the accuracy of a method can be determined because the "true" value can be estimated from the testing results. Personnel being trained should also evaluate individual instructors, effectiveness of the training session, and problem areas in method documentation.

Audits

Audits of the field crews are used to ensure and document the correct implementation of methods and field QA activities. Audits can identify problems with methodology implementation or innovative changes in methods that could be implemented for the entire project. The audits can also be used to identify and

summarize field crew problems with the methods.

Audit findings should be summarized into reports and provided to the appropriate project personnel. The information contained in the reports should be used to correct problems in data collection. The information should be used in a constructive manner, not for discipline.

Remeasurement System

Variability in measurements is expected between individuals and between crews. The remeasurement program provides actual data of this variability (QC) and provides project management an opportunity to make changes when needed and provides confidence levels for project results. The remeasurement program should be designed to address the project needs. It is important that a repeat measurement (QC) of a subset of plots be undertaken to determine data quality values. The plots selected for repeat measurement should be determined at random. This ensures that the field crews will measure each plot carefully because each plot has an equal chance of being remeasured.

Use of Data Quality Information

The data quality information (QC) should always be attached to the results rather than remain as a separate report or document. The attachment of data quality information to the program results allows the reader to interpret the conclusions and the appropriateness of the selected method in the context of the data quality. The data quality information can be used to evaluate the method data quality, especially when the performance criteria were estimated from historical data. Precision estimates can be used to establish the confidence in conclusions based on the data. For example, if data had poor precision, then confidence in results will be poor.

Qualitative information can also be useful in interpreting the results or in evaluating the effectiveness of a method. This information can be summarized from training session evaluations, audit reports, and/or end-of-field-season crew debriefings. This information can be used to identify interpretation problems with method documentation and/or alter the emphasis of the training session for subsequent field seasons.

In any project, the management needs to evaluate all of the QA information annually. In subsequent years, data quality information may be used to modify the projects' objectives, change the method, improve the training session, or other uses. It is then necessary to revise the affected information and re-adjust the program. This process should be viewed as continually changing to improve the overall program results.

CONCLUSIONS

Deviations in the methods and measurements occur between individuals and crews. A QA program will reduce the variability and provides project management qualitative and quantitative to make improvements in the project. Quality assurance for documenting data quality should be included in the project organization and planning. To accomplish this, QA personnel need to be involved with overall project planning during the development of the project. Quality assurance concepts used in the North American Sugar Maple Decline Project provide a logical progression from problem statement in measurable terms to collection of appropriate data from which to draw conclusions. The results discussed in this paper demonstrate that QA activities can improve and quantify the quality of the data even for subjective measurements. In addition, the use of QA information and QC data can be used to improve the quality of data in subsequent years.

The following general procedures are recommended:

1. Develop and test consistent, well-documented procedures to ensure high quality data.
2. Implement training prior to data collection to ensure crew familiarity with methodology.
3. Conduct audits to identify problems concerning the implementation of methodology and promote communication within the project.
4. Collect remeasurement information so that data quality can be estimated and use the information during the interpretation of results.
5. Plan for QA procedures and activities in all programs so that data quality can be assessed and improved.

ACKNOWLEDGEMENTS

The data for this document were provided by the cooperating groups in the "North American Sugar Maple Decline Project", (USDA Forest Service, Forest Pest Management; Forestry Canada; Maine Forest Service; University of Massachusetts; Michigan State University; New Hampshire Department of Resources and Economic Development; SUNY College of Environmental Science and Forestry; Vermont Agency of Environmental Conservation; and Wisconsin Department of Natural Resources). The authors would like to thank all of the cooperating groups for providing the data used in this publication. In addition, appreciation is extended to the reviewers for providing constructive comments which improved the overall quality of the paper.

The research in this report has been funded by the US Environmental Protection Agency and the USDA Forest Service through the Quality Assurance Project and Eastern Hardwoods

Research Cooperative of the Forest Response Program of the National Acid Precipitation Assessment Program, and Forestry Canada. This document has been prepared at the EPA Environmental Research Laboratory in Corvallis, OR, through contract # 68-C8-0006. It has been subjected to the US-EPA's peer review and administrative review and is approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Table 1. Class codes, percentage classes, class range, and acceptable error range (dominant and codominant trees only) for measures of branch dieback, foliage transparency, foliage discoloration and dwarfed foliage.

Class Code	Percentage Class	Class Range	Acceptable Error Range
00	0	0	0 - 5
05	5	1 - 5	0 - 15
10	10	6 - 15	1 - 25
20	20	16 - 25	6 - 35
30	30	26 - 35	16 - 45
40	40	36 - 45	26 - 55
50	50	46 - 55	36 - 65
60	60	56 - 65	46 - 75
70	70	66 - 75	56 - 85
80	80	76 - 85	66 - 95
90	90	86 - 95	76 - 100
99	100	96 - 100	86 - 100

Table 2. Measurement precision for sugar maple crown condition ratings for the 1988 and 1989 field seasons.

Crown Category	'88 % Agreement*	'89 % Agreement	Change ('89 - '88)
Branch Dieback	95.6	96.7	+1.1
Foliage Trans.	90.9	91.8	+0.9
Foliage Discolor.	91.3	99.1	+7.8
Dwarfed Foliage	88.3	98.8	+10.5

* % Agreement: ± 1 class between original and remeasurement data for dominant and codominant trees and ± 2 classes between original and remeasurement data for intermediate and suppressed trees.

Table 3. Between-crew crown rating measurement precision for sugar maple, for the 1988 and 1989 field seasons.

Crown Category	'88 % Agreement*	'89 % Agreement	Change ('89 - '88)
Branch Dieback	79.2	95.6	+16.4
Foliage Trans.	74.3	93.8	+19.5
Foliage Discolor.	74.4	99.3	+24.9
Dwarfed Foliage	73.0	99.9	+26.9

* % Agreement: ± 1 class between original and remeasurement data for dominant and codominant trees and ± 2 classes between original and remeasurement data for intermediate and suppressed trees.

- Figure 1. 1988 and 1989 original vs. remeasurement rating class for dwarfed foliage, sugar maple only (Note: Each number represents the frequency of occurrences for a particular pair of original and remeasurement values).
- Figure 2. 1988 and 1989 original vs. remeasurement rating class for branch dieback, sugar maple only (Note: Each number represents the frequency of occurrences for a particular pair of original and remeasurement values).
- Figure 3. 1988 and 1989 original vs. remeasurement rating class for foliage transparency, sugar maple only (Note: Each number represents the frequency of occurrences for a particular pair of original and remeasurement values).

FIGURE 1

Class Deviation

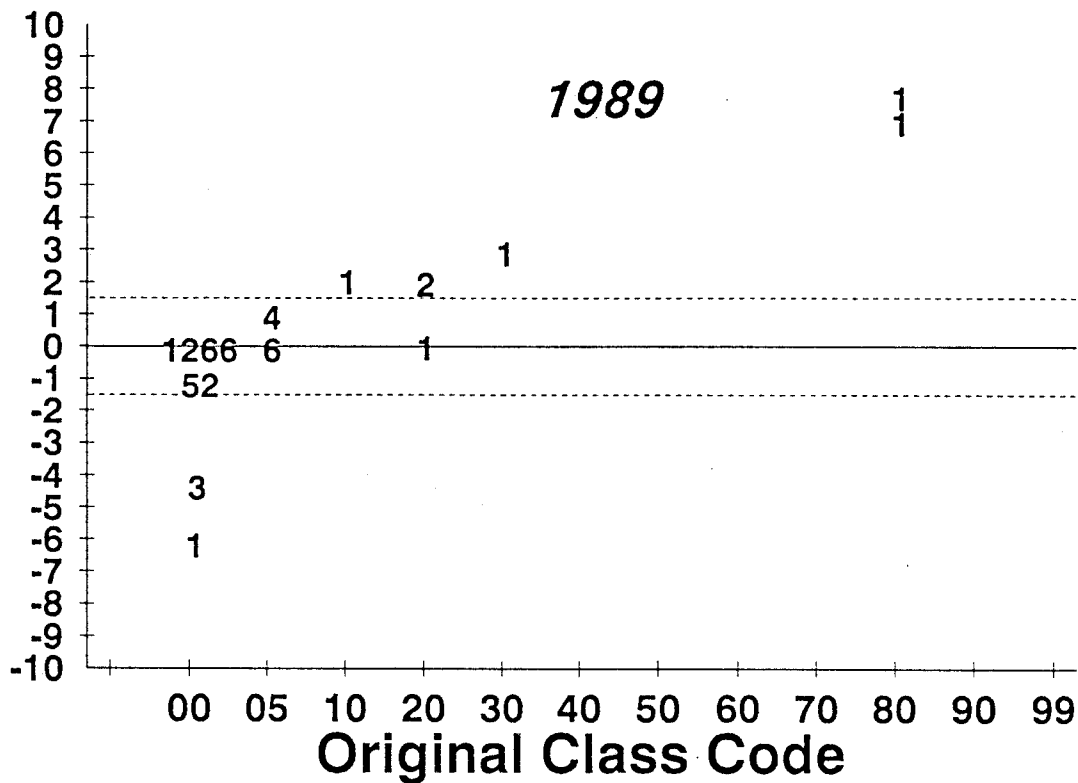
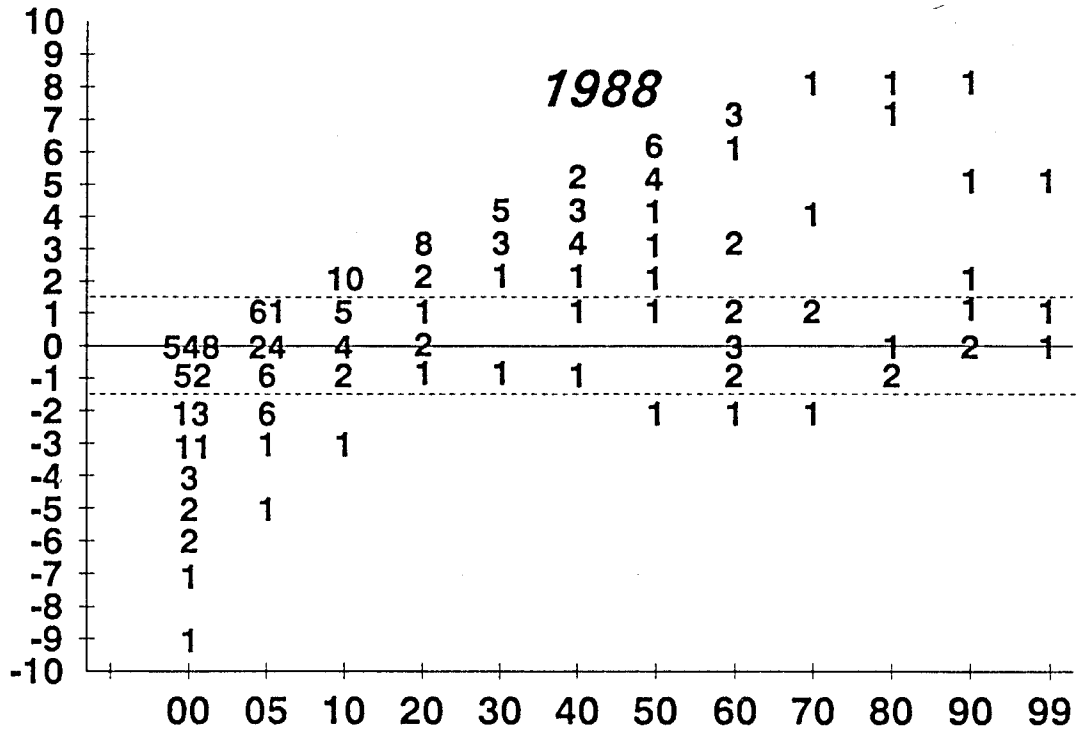


FIGURE 2

Class Deviation

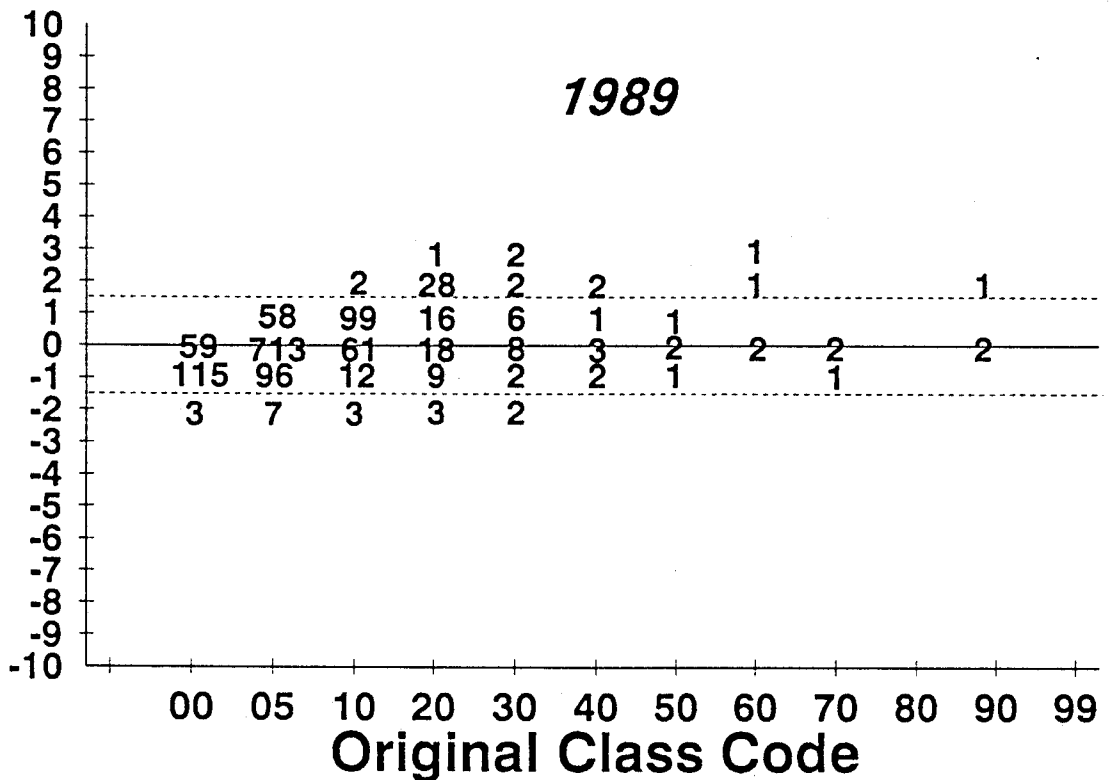
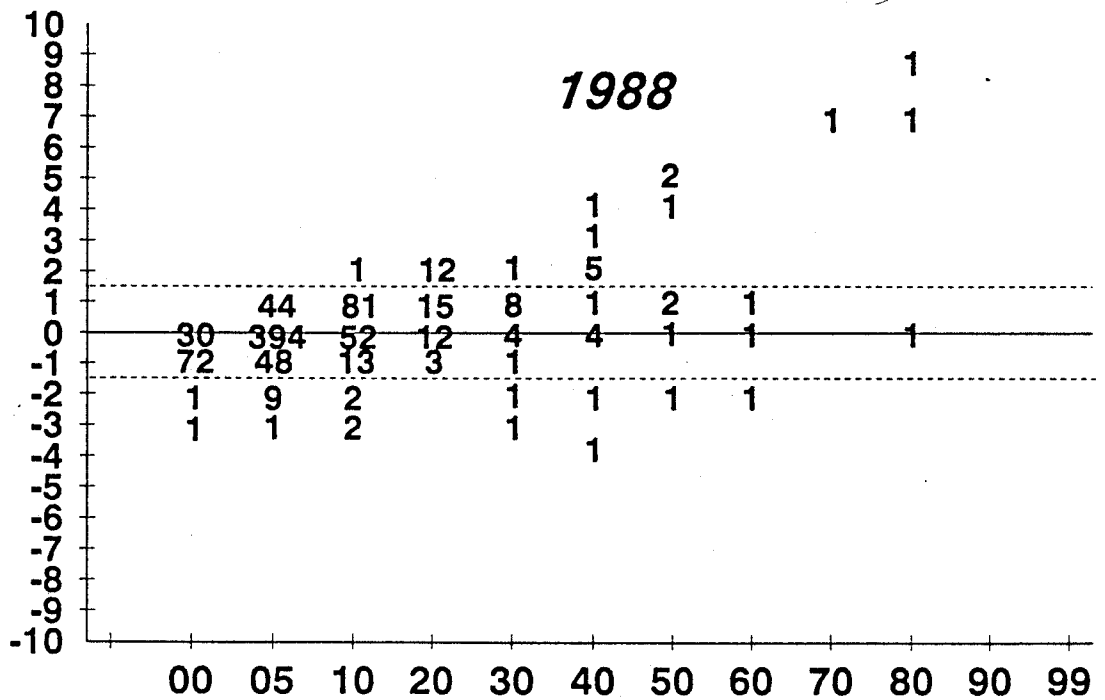
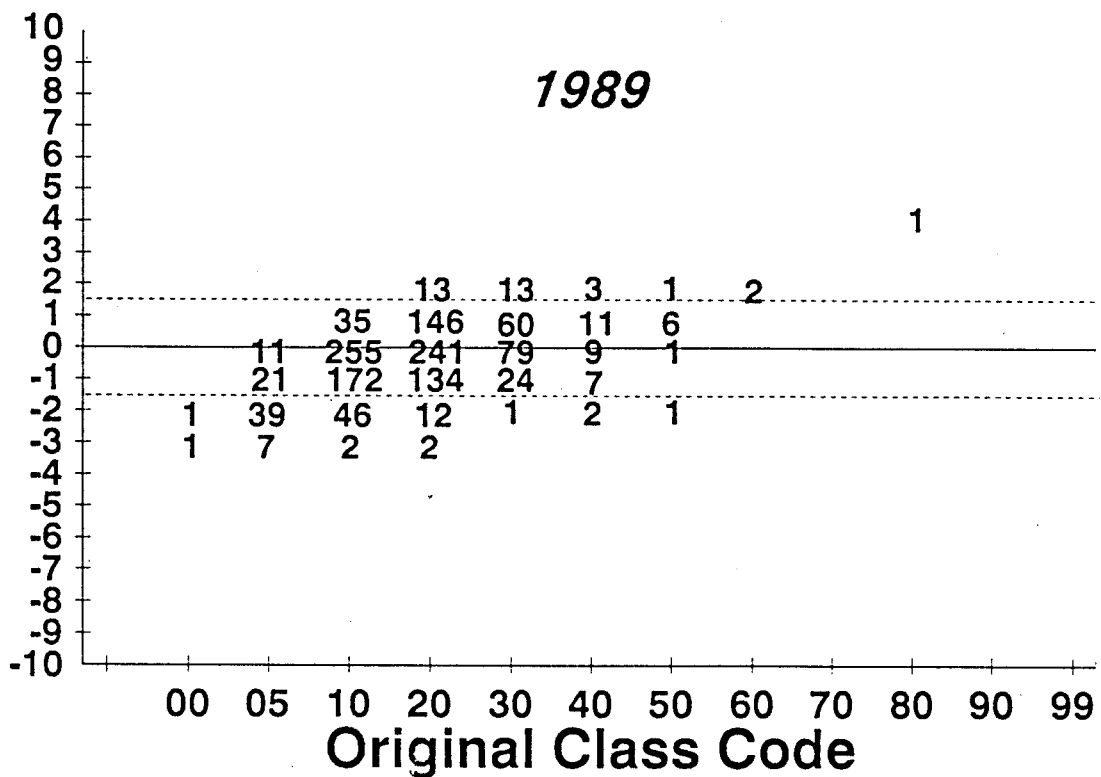
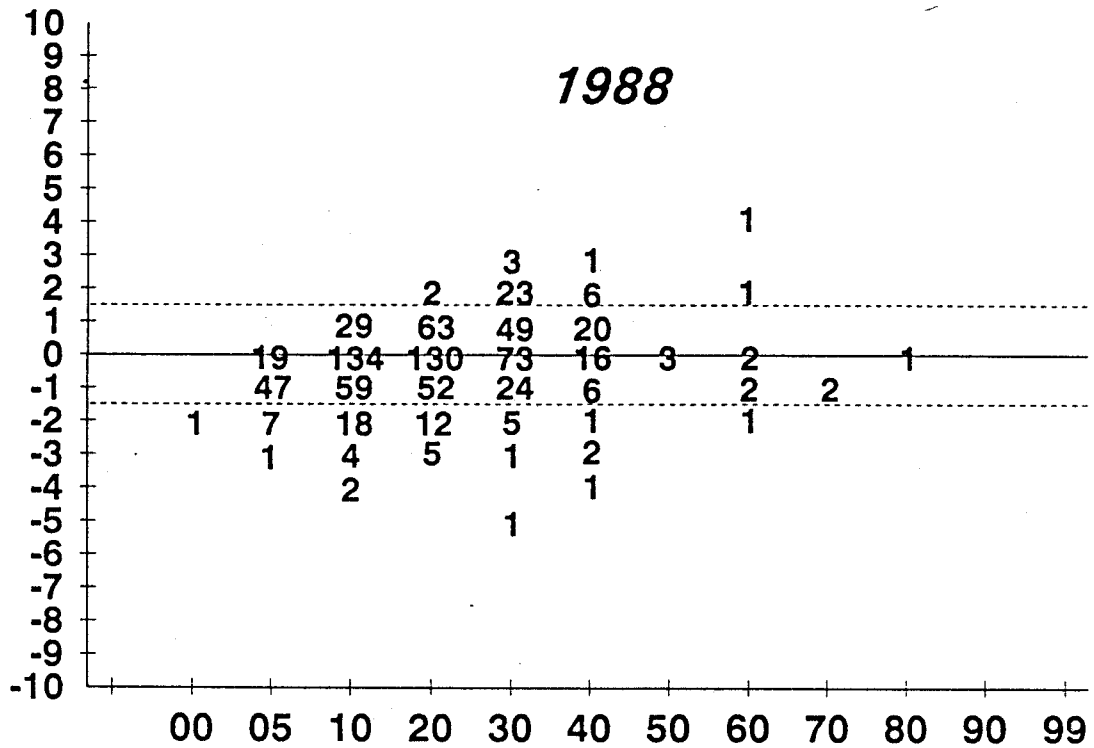


FIGURE 3

Class Deviation



RESEARCH'S HIDDEN ASSETS -- TAPPING INTO EMPLOYEE KNOWLEDGE
AND EXPERIENCE 1/

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Introduction:

The United States Forest Service is an old-line organization created in 1905. Like all organizations, the Forest Service has accumulated procedures and processes and ingrained patterns of behavior over time. Several approaches have been tried to increase the organization's efficiency and effectiveness. Finally, a bold program of empowering employees and managers to reduce bureaucratic red tape, and to promote efficiency and effectiveness, was tested and it proved to be wildly successful. Today I want to share information about some results of that program, especially as they apply to the Research branch of the Forest Service.

The Need for Change:

Over time, the burden of regulations, reduced real budgets, new laws, increasing public demands, and internally imposed constraints, have seriously compromised the ability of Forest Service employees to carry out their jobs. The significance of these barriers to effective organizational performance became clear as pressures on the organization created demands for more efficiency and effectiveness. About 10 years ago, surveys of employee morale and attitudes confirmed management's sense that we had to find better ways of carrying out our business.

Within the Research branch of the Forest Service we found nagging problems that inhibited our effectiveness and productivity. These problems included: poor public perception of our goals or mission; inflexible program development; fragmentation of broad problems along functional lines; inflexible program-funding guidelines; inability to acquire funds to capitalize on emerging research opportunities; excessive paperwork and administrative burdens that distracted scientists from the primary function of "research;" and inflexible recruitment and hiring practices that made it difficult to compete for the best people. All of these problems are symptomatic of an organization that has become trapped in red tape.

Our first efforts to improve organizational effectiveness centered around improving functional processes already in place. Productivity Improvement Teams were the final expression of this approach. However, despite much activity, the results provided only marginal improvements in efficiency, and those did not serve to relieve the pressure because the demand was outpacing the rate of improvements.

1/ Presented at the XIX Congress of the International Union of Forestry Research Organizations; Section S6.06 Research Management. Montreal, Canada, August 6-10, 1990.

Finally, in 1984, then Associate Chief, Dale Robertson, came to the realization that the only area in which no major effort at improvement had been tried was to reduce the bureaucratic red tape. Discussions among the leaders of the Forest Service and an organizational consultant led to three major conclusions:

1. Employees were the most impacted by red tape and they knew what barriers prevented them from being effective. Employees could spearhead a drive to eliminate or reduce barriers to productive work;
2. To empower employees to take action and to make or recommend changes required a major cultural change in the Forest Service; and
3. In order to change the culture of the Forest Service, it was important to test the idea in a few units rather than trying to impose change from above.

In 1985, four units were designated to test or PILOT the new approach. In 1987, my Station, the Northeastern Forest Experiment Station was added to the original four units.

PILOT, The Guidelines:

The test units, which I will call PILOT units, were given the following simple guidance.

1. Laws and basic regulations remain intact. Innovations, risk-taking, and experimentation must be conducted within legal bounds.
2. All funds will come to the unit as a "bucket of money." Funds will be managed for results, not to zero out accounts. Work must be accomplished within the limits of funds allocated. All savings from efficiencies remain with the unit.
3. PILOT is bottom-up. Employees have the lead to recommend changes and managers are to test those recommendations.
4. Personnel ceilings are removed.
5. There are no failures. Ideas that do not work will be viewed as learning experiences and a new idea tried.

Beyond these simple top-down instructions the units were given wide latitude to restructure and change their organizational and operational procedures.

Changes in the Organizational Culture of the Forest Service:

Cultural changes had to be made in the Forest Service if the empowerment of employees was to be a successful approach to increasing efficiency. These were not minor changes. In the U. S. federal government, there are layers of review and oversight on most employees. For example, expense vouchers are typically reviewed at several levels. As one Navy pilot wrote recently, I fly a \$40 million airplane and lead 10 to 12 other airplanes. In addition, I am

responsible for the 310 people who support those flights, yet my supervisor has to examine and approve a \$3.25 receipt for long distance calls made for the government. The example is striking in what it says about values when government employees are involved. The long history and acceptance of such procedures had to be overcome.

The major cultural change that was necessary for PILOT units to be successful was to free up employees from the heavy controls and rigid processes to which they had become accustomed.

The PILOT culture was simple: Employees are dedicated and approach their work as professionals. They are vitally interested in improving their jobs for personal satisfaction, and to better serve their customers. If employees are empowered to improve their jobs they will do so.

Employee Involvement:

The PILOT program differs from traditional employee suggestion programs in several ways. Most significant is the empowerment of employees to make suggestions that will be tested by management unless counter to the basic guidance, and to take action based on common sense. It also differs in that the "reward" to employees is not monetary, but rather in terms of the personal satisfaction that comes from trust and the ability to take action to improve the organization. Finally, employees are encouraged to make suggestions regardless of whether or not the suggestion was focused on their own part of the organization. Thus, under PILOT, employees could modify their own work environment as well as that of the entire organization.

To get started at the Northeastern Station, employees were asked:

- * If you were operating the Forest Service as a personal business, what changes would you make in operating procedures?
- * What regulations, processes, and reports would you eliminate?
- * How would you improve customer satisfaction?
- * What new perks or benefits would you give to your employees?

All employees were assured that the Station Director would personally review their ideas, that no ideas would be implemented that harmed anyone, that no retaliation would occur for controversial proposals, and that all feasible ideas would be tested.

Employee Response:

Employee response was overwhelming and revealed a wealth of pent-up ideas just waiting for an opportunity to be released. At my Station, virtually all employees have participated during the past three years, leading to wide acceptance and ownership of the PILOT program. Proposals came from all levels of the organization and addressed personal, unit, and National level topics. For example, during the first two years of PILOT at the Northeastern Station, a secretary contributed 20 proposals for change, most of which were adopted.

The Results:

During the first two years of PILOT at the Northeastern Station, 330 employees made over 700 suggestions. Initially most suggestions dealt with employee related concerns, but after a few months major suggestions were made about how to better organize to do research and how the entire Federal government should change some of its procedures. Here are some of the intangible results:

- Of all the proposals, PILOT units found that between 70-75 percent were within the authority of the senior line manager, another 15 percent were within the Chief of the Forest Service's authority, and the remainder required change by another agency or organization, e.g. Office of Management and Budget or Congress.
- employee morale improved;
- communications greatly improved in all directions - up, down, and across the organization because PILOT created an open climate of trust and respect;
- innovation rather than process became the guideline;
- employees learned more about the forces that shape government service because they had a vested interest in various proposals and followed the arguments for and against the ideas.
- employees in PILOT units turned down promotions to nonPILOT units.

Tangible results are equally valuable. Here are a few examples.

- The Office of Personnel Management is testing a "Direct Hire and Retention" program proposed by our staff. This program allows managers to evaluate the qualifications of prospective employees and make job offers on the spot. In addition to this hiring authority, signing and retention bonuses can be paid. All these steps are intended to make the government competitive as the labor pool shrinks in the future. This test will be evaluated periodically, and the Office of Personnel Management will determine at the end of 5 years whether or not to extend the program to the entire Federal government.
- PILOT suggestions led us to try new research organizations. The Forest Service research program is functionally organized and that has created barriers to effective team approaches to problems. Problems would be assigned to a functional research unit and the research wouldn't always be successful. Under PILOT, we picked two key regional problems traditionally assigned to timber management research, then asked any Station scientist, who thought they could contribute to the solution, to attend several planning meetings. Out of this came two teams involving not one, but eight different disciplinary areas. The teams have made remarkable progress and users who are also involved are pleased with the outputs.

- We also have tried a more radical organizational change. We have an urban forestry unit located at Syracuse, New York. This unit specializes in characterizing urban vegetation and the urban-wildland interface. The research leader, after spending a year on sabbatical at the University of California at Berkeley and seeing the myriad of urban interface problems on the west coast, proposed that he be permanently located in Berkeley while continuing to direct the research effort assigned to the Syracuse unit. So far this arrangement has worked well. By using FAX and our computer network, he has been successful in managing a widely dispersed program and, in doing so, has garnered resources for the work that would not have been available if all the scientists had been located together. This experience not only evaluated team productivity when the team was dispersed, but also crossed traditional research station boundaries, thus destroying another traditional barrier to effective research.
- Another PILOT idea was to allow employees to carry over up to 24 hours from one pay period to the next. This suggestion, now government wide, has saved an untold amount of overtime pay and sick leave. Our employees are on a "maxiflex" schedule where they can adjust their times of arrival and departure at the workplace, thus adding to or using their carryover hours with their supervisor's concurrence.
- Examples of suggestions implemented on National Forest PILOT units include: gain-sharing which is a distribution of 10 percent of the savings from PILOT suggestions back to the employees, the use of credit cards for government purchasing agents, and one-stop approval of permits.

Implications for Managers:

The results from the PILOT units fully support the premise of PILOT, namely that employees, when empowered, will perform in creative and professional ways. As an administrator, I have had to become more flexible, say yes very often, and most of all have full trust and confidence in my subordinates. That trust has been amply rewarded. No PILOT unit has yet been embarrassed by any form of employee misconduct related to PILOT empowerment. Under PILOT, outputs and morale are up and there is a government-wide recognition that we are pioneering new ways to manage in government service.

Conclusion:

After five years of testing the PILOT program was clearly successful. Not only were the PILOT test units enthusiastic, but many other units were seeking to implement PILOT. As a result, the Chief of the Forest Service has chartered a new management philosophy for the Forest Service based on PILOT. Carefully, the Chief did not order units to adopt the philosophy, but has instead allowed the philosophy to diffuse throughout the organization. Where there has been managerial resistance to adopting the philosophy, we are seeing employees organize to impress upon management how much they would like to use the PILOT approach.

A copy of the Charter for the new Forest Service Management Philosophy is attached.



*Chartering a
Management Philosophy
for the
Forest Service*

Below the title, there are two symmetrical, flowing decorative flourishes that mirror the ones above the title.

Transition: From Pilot Test to Management Philosophy

In 1985, with the launching of the National Pilot Test, the Forest Service set out to explore ways to loosen up the constraints on our people and to overcome stifling bureaucratic forces, with the aim of improving customer service and enhancing quality and productivity. From this five year experiment a revitalized spirit and a new "people-oriented" philosophy have emerged. We've learned that tapping the full strengths and talents of the workforce is brought about by loosening controls, reducing red tape, and providing people with more freedom and authority at all levels of the organization. More recently, many organizations in the Forest Service have begun to move in this same direction, initiating special programs to promote teamwork, creativity, innovation, closer ties to our customers, and more creative approaches to our problems.

Results from the National Pilot Test and from these local efforts clearly indicate that this philosophy works and that it is now time to move this "new thinking" and new approach to management from Pilot Test experimentation to center stage—to institutionalize this philosophy Servicewide.

From Principles to Practice—A Working Philosophy

Traditionally, employees refer to management direction to determine limits, to inhibit action, protect turf, or measure deficiencies. This "people-oriented" philosophy reverses this thinking; the tone of this direction is to expand our possibilities. This charter for managing the Forest Service will be a day-to-day guide for new behavior and more effective management. Over time, every directive, program and activity will be reconciled to this philosophy. This philosophy will be the "litmus test" for new initiatives and problem solving.

Adopting this philosophy Servicewide is a challenging and long-term effort. Change is always difficult: Cultural change even more so. The struggle to embrace this philosophy and to truly set it to work will take place in the trenches of the workplace: by the district clerk reducing the red tape for local publics; by the field staff specialist assuming the new roles of "barrier basher" and "innovator"; and by firstline supervisors taking risks and making the leap to empower his or her workforce.

Once we began our journey toward this philosophy, the course was irreversible. But there is no hard and fast timeline for adopting this new approach. Each manager (and organization) has the discretion to establish the pace and style of implementation. How fast we solidify our commitment to these new ideas and principles will depend upon how many champions rise up "to make it happen". Fortunately, the Forest Service has never had any shortage of champions.

CHARTER

Preamble

Over the past 80 plus years the Forest Service has been one of the most responsive and effective organizations in government. Our reputation for “excellence” is one to be proud of, but continued success depends not on holding the status quo, but on our ability to adapt to changing times. Our job has become far more complex and challenging than at anytime in our past. Demands on our time and dollar resources are increasing; issues are vastly more complex; and our external environment is becoming far more turbulent. We simply must find ways to expand beyond current limitations and ways of doing business if we are to continue to manage the National Forest lands and carry out our Research and State and Private Forestry Missions effectively.

We can meet this challenge by departing from the traditional ways we do business, by refusing to accept mediocrity and to be overwhelmed and stymied by the “bureaucracy,” and by adopting the philosophy that has evolved from the Pilot Test. In the framework of this approach, the spectrum of what is possible—the “field of play”—is redefined. The field becomes larger and boundary markers fewer and farther apart. Our opportunities and possibilities for meeting today’s demands and challenges are greatly enhanced.

This philosophy is people oriented. Simply put, it means that we stake our future on our people: the workforce is the key to sustaining and improving the qualities of excellence that have long characterized the Forest Service. Our approach to management comes now from a different perspective. Rather than directing people to manage in accordance with established rules and procedures, we define our objectives and focus on creating an environment that will allow our people to apply their full resources to the accomplishment of the job.

Key Principles of Management

The following principles are set out to guide our people in adopting this philosophy and making the transition to a new culture in the workplace:

The Forest Service is a workplace where—

- All directions, procedures, and operations begin with a focus on the needs of our customers.
- Quality results count; process is secondary.
- People are important, trusted, and empowered by being given the fullest authority and responsibility consistent with their capabilities.
- People have the opportunity and operating flexibility to exercise independent judgment.
- Individual skills and cultural diversity are valued and sought out as important assets of the organization and key resources for solving problems.
- Managers provide a climate where responsible risk-taking is encouraged and rewarded, and failures are acceptable learning experiences.

- Creativity, innovation, and entrepreneurship are viewed as critical to our success and fostered at every level of the organization. Pilot testing new ideas on the cutting edge is a traditional mode for remaining competitive.
- The manager's role (both line and staff) in the organization is one of guiding, educating, advising, and encouraging rather than regulating and controlling. The tone of direction is shifted from "limits and controls" to one of "promoting people's full potential—expanding and encouraging ideas and skills."
- Nonconformists, risk-takers, and innovators are encouraged and are key to meeting the challenges of a changing future.

Guidelines and Limits

Operating freedom and flexibility, new ideas, creativity, risk-taking and experimentation do not preclude sound control, accountability, and an absolute bias for integrity. The Forest Service clearly has a stated mission, strategies, central thrust, and priorities that dictate what work will be done. Likewise, there are laws and rules for every organization that define the boundaries of operations and are basically outside the arena of innovation and experimentation. The following policies provide guidance to managers for operating under this new philosophy:

Legality. Innovations, risk-taking, and experimentation must be conducted within legal bounds. If it's not legal, we don't do it.

Basic Policy. Policies that set the major courses of action for the Forest Service must not be compromised as we explore creative and innovative ways to get the job done.

Budget Integrity. At all levels of the organization, work is accomplished within the limits of the funds allocated.

Targets are important. Goals, priorities and targets set by Congress and the Administration are important and we will do our best to achieve them.

Philosophy

Our basic approach to managing our people can best be summed up as follows:

We have dedicated and hardworking people who want to do a quality job. We trust them. In caring for the land and serving people, our people should use common sense and their best judgment, and then go ahead.



F. Dale Robertson, Chief
December 19, 1989

Experiences in Developing a Strategic Plan
for the 90's for USDA Forest Service Research

Jerry Sesco, Deputy Chief
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Washington, D.C.

Introduction

The previous paper which discussed strategic planning in public forestry research organizations set the stage for this paper. For the past two years, USDA Forest Service Research has been developing a strategy for its research programs. In this paper, I will discuss some of our experiences in the development of this strategy. Specifically,

- Why did we decide to prepare a strategic plan?
- What are the components of the plan?
- What lessons did we learn which may be useful to others?
- How do we plan to implement the plan?

At the outset, it might be useful if I defined what I mean by "strategy." "Strategy" is a much used and often misused word today. To understand what strategy is and how it relates to the operating side of an organization, consider two facets which are critical to the survival of all organizations:

What the organization wants to be

and

How it should get there.

These two facets are often confused. An organization's future self-definition--what it wants to be--and its planning and day-to-day operational decision making--how it gets there--are related, but separate, dimensions.

Unfortunately, the word strategy is used rather casually today--it confuses the what and the how.

Managers talk about "their pricing strategy," "their budget strategy," and "their recruitment strategy." But, these are all related to how an organization gets to where it wants to be. So, when I say "strategy" I mean the nature and direction of the organization, its basic purpose.

The clearest definition I've heard of strategic planning is in a quote by the great hockey player, Wayne Gretsky: When asked the secret of his success as a hockey player, he replied, "I skate to where I think the puck will be." So, the objective of developing a strategy for an organization is to provide direction which will confront the issues of the future.

Why did we decide to initiate the development of a strategic plan in the Forest Service Research organization? Organizations are somewhat like living

organisms in that they, too, must be capable of adapting to changing environments if they are to survive. The environment of Forest Service Research changed and we needed to adapt.

The 1960's and 1970's were relatively successful years for Forest Service Research. Budgets were increasing and several new laboratories were constructed. But, the 1980's were a decade of decreased funding, compounded by efforts to reduce the Federal deficit. During the 1980's, we closed several laboratories and reduced the number of scientists by 25 percent. By the late 1980's, our budget in constant dollars was about the same as 10 years earlier. Needless to say, we had some concerns and decided to initiate some actions.

We hired an outside consultant to provide an objective assessment of our competitiveness in the overall research community and our responsiveness to customer's (user's) needs. Based on the results of the consultant's report, we undertook several actions--the most significant was the development of a strategic plan.

Developing the Strategy

The "Strategy for the 90's for USDA Forest Service Research" is the product of an assessment of our mission, program, organization, and cooperation. Senior executives in Forest Service Research were involved throughout the strategy development efforts. The process for developing the strategy included several 3-day discussion sessions which included the Deputy Chief, Associate Deputy Chiefs, Station Directors, and Staff Directors. The purposes of the sessions were to: develop a better understanding of the Forest Service Research mission; determine trends affecting natural resources; evaluate current strengths of Forest Service Research; define issues, problems, and research opportunities; and estimate the level of support for current and future programs. From these discussions, a draft strategy was developed and subjected to extensive internal and external review. From these review comments and further discussions, the Deputy Chief for Research finalized the strategy.

Based upon a shared agreement of trends, mission, goals, and research capabilities, a research program strategy consisting of three major components was selected for emphasis. The three major components are:

1. **Understanding ecosystems.** The focus of this component is on understanding the structure and function of forest and range ecosystems, including mechanisms that control processes and the interdependency among ecosystem components. It is intended to provide understanding of how ecosystems affect, and are affected by, natural and human-made environmental changes. The areas of concentration in this component include ecological processes, biological diversity, endangered species, global change, atmospheric deposition, surface and ground water pollution, reforestation, and tropical forestry.

2. **Understanding people and natural resource relationships.** The focus of this component is on how people perceive and value the protection, management, and use of natural resources. Areas of concentration will include socioeconomic factors associated with the wildland/urban interface, rural development, rural diversification, international trade, customer satisfaction,

value differences among user groups, and the influence of urban culture on forest uses and practices.

3. Understanding and expanding resource options. The goal of this component is to determine which protection and management practices and utilization systems are most suitable for the production and use of natural resources. Although all resources will be studied, increased concentration will be given to studying options for the production and uses of non-wood outputs, such as water, fish, wildlife, and recreation resources. Research on extending the use of wood as a raw material, including recycling, will also be increased.

Lessons Learned

Consultants were used sparingly, but effectively, to help develop the strategy. Consultants helped design the process, served as meeting facilitators, and critiqued meetings and documents. They were not, and we feel should not be, involved in the decision making processes involved in developing the strategy. They assisted by providing an outside perspective and by asking useful, pertinent, and piercing questions.

The process for developing the strategic plan was deliberate. We asked the senior management team to be fully involved in the entire process, and to "buy-in" to the planning steps outlined by Bryson (1988)¹. There was general agreement that the steps outlined were acceptable. However, the mention of "processes" had negative connotations to some of the senior executives, who perceived "processes" as getting in the way of "dealing with substantive issues". We recommend keeping the strategic planning steps simple and transparent, but to emphasize the objectives and interrelationships of the various steps of the effort. Excessive detail may turn off some participants, and encourage participants to be detail-oriented, which is generally not needed or even desirable in strategy development. Striking a balance between those who want the processes and interrelationships laid out and defined in detail and those who want only general concepts is the challenge.

It is important to re-emphasize the need for full involvement of senior managers in strategy development. All senior managers in Forest Service Research (Deputy Chief and Staff, Station Directors, and Staff Directors) were involved on the strategy development team. This is helpful as the team works toward consensus on issues. Our experience suggests that the highly intuitive team members, who can offer insights and long-range views on diverse issues, should be encouraged to freely express their views and to challenge others to be proactive in their thinking.

It should be recognized that at various times in the strategy development process participants may be asked to think about issues at different levels of the organization. At times, managers will need to think about issues relating to the total organization, and at other times they will need to think about issues at lower organizational levels. This appeared to be difficult for most managers because of their parochial interests. We recommend that it be made clear which level of emphasis is needed for each planning session. In addition, from time to time managers should be asked to explain whether their statements are coming from a corporate or a position-dependent point of view.

Acknowledging the mode and discussing it should help in building a team, reaching consensus, and setting direction for the future.

It took longer than anticipated to move through the strategy development process and prepare a plan. Our intention was to have a plan completed in a year, but it took more than a year and a half. We recommend the process not be rushed. When a research program direction is first drafted, participants need time to understand and refine the proposed direction. Revisions and enhancement of the draft document proceeded slowly. There was a need to recycle significant changes in the document through the group of participants. It also took time to collect and assimilate review comments from people inside and outside the organization. We feel it is important to have patience in these phases.

One of the most difficult aspects of research strategic planning falls in the area of futuring or defining potential future problems. It involves extrapolating beyond the current trends to project what might be future problems and areas of fruitful research. It was difficult for managers to become futurists--to define broad-scale future problems. While brainstorming and nominal group techniques are useful for this phase, we think that futurist specialists should be brought in to make these sessions more effective in defining future problems, thinking strategically and being more proactive.

We believe there are some management philosophies and approaches that can help a research organization to be more proactive. Scientists need to be encouraged and rewarded for addressing high-risk, potential problems. They also need to be encouraged to work in small teams (skunkworks) to generate new ideas. Potential future problems are more likely to be identified and revealed (filtered up) in this type of an environment.

Developing the strategy per se is only part of the goal. Perhaps the greatest value from developing a strategy comes from the improved ability to think and act strategically. Only when that takes place will it fully serve its intended purpose.

How Do You Make A Strategy Happen?

A full discussion of implementation of a strategic plan is a subject which would require another paper in itself. Briefly, strategic management is a continuing process. Putting a strategy in place requires linking what the organization wants to become with how it should get there. Nowhere is the perseverance of an organization management tested more acutely than in the area of implementing strategy. A well formulated strategy is the first step toward effective implementation, because every plan that must be developed, and every decision that must be made, can be tested against this mental picture of what you want the organization to be.

^{1/}Bryson, John M. 1988. Strategic Planning for Public and Nonprofit Organizations. Jassey-Boss Publishers. San Francisco, CA. 311 pages.

THE INTERNATIONAL FOREST PRODUCTS PROGRAM AT THE FOREST PRODUCTS LABORATORY: ROLE FOR THE UNITED STATES IN PROMOTING FOREST PRODUCTS INTERNATIONALLY

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SUMMARY

The U.S. Department of Agriculture, Forest Service, Forest Products Laboratory (FPL), has promoted international cooperation since it was established in 1910. A new work unit supporting an International Forest Products Program was recently initiated at FPL. This new unit, along with other units of the Forest Service and our research colleagues in the academic and industrial sectors, could take a lead role in promoting forest products utilization internationally.

Keywords: Forest products, International Forest Products Program, forest products research

INTRODUCTION

Although the USDA Forest Service, Forest Products Laboratory (FPL), in Madison, Wisconsin, was established primarily to serve U.S. research needs, it has always had an international dimension as well. Established in 1910, FPL began receiving international recognition and foreign visitors during its first decade (Youngs 1987). FPL regularly receives requests for information and advice from all over the world. However, most of these requests are from industrialized countries (Ingram et al. 1987). We must find more effective ways of transmitting information to our colleagues in less developed countries as well. The Bellagio II Conference recognized this need by endorsing utilization and market research as one of five areas requiring additional support (Rockefeller Foundation et al. 1988).

In the several decades after it was established, FPL broadened its international involvement through international contacts with staff scientists. For example, after his retirement, a former FPL Director became co-director (with a Filipino counterpart) of the Philippine Forest Products Laboratory (now the Forest Products Research and Development Institute). He was instrumental in establishing its research program and a program to send scientists to FPL and the University of Wisconsin for professional and advanced academic training. Other efforts during this period included assistance to Costa Rica, Ecuador, Chile, Bangladesh, and many other countries.

In the 1970s, FPL, with support from the U.S. Agency for International Development (USAID), launched a program to evaluate and demonstrate the potential for using mixed tropical hardwoods for a variety of products. This effort culminated in a major international conference in Madison, Wisconsin, in 1978. (USDA Forest Service, Forest Products Laboratory, 1978).

¹ The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. This article was written and prepared by U.S. Government employees on official time, and it is therefore in the public domain and not subject to copyright.

In the mid-1980s, the U.S. Congress mandated that the USDA Forest Service supplement its research efforts in tropical forestry, including forest products. FPL joined other Forest Service units in this effort, which became popularly known as the Caribbean Initiative. FPL efforts resulted in the preparation of a report entitled "Forest Products From Latin America: An Almanac of the State of the Knowledge and the State of the Art." Although the focus of the report is Latin America, it should have broad application to research efforts and information transfer in other tropical areas.

The international efforts of FPL were strengthened and institutionalized in 1988 with the establishment of the International Forest Products Research, Development, and Application Program. This paper describes how this new unit could catalyze and coordinate FPL and Forest Service efforts to promote forest products utilization internationally.

INTERNATIONAL FOREST PRODUCTS PROGRAM

The mission of the International Forest Products (IFP) Program is to "facilitate forest products research through an international program of research, development, and application between FPL and other Forest Service units, universities, and related institutions throughout the world." The IFP unit has modest resources and must rely on its parent organization and others to do the actual research. The unit's role is to help initiate and guide these efforts. In pursuit of this objective, activities are underway in the areas of (1) supporting programs in developing countries, (2) coordinating forest products research, (3) exchanging scientists, and (4) identifying applicable foreign technologies.

Supporting Programs in Developing Countries

We believe that the best, and perhaps only, way to promote the application of new technologies in developing countries is through one-on-one relationships between research institutes and between scientists in developed and developing countries. The need to support research institutes in developing countries is well recognized. We should help build upon the excellent research capability that already exists in many centers. Well-planned national research will be more effective than imported research (World Bank, Food and Agriculture Organization 1981). As discussed previously, networking or twinning arrangements between institutes in developed and developing countries are effective ways of providing support. Another is cooperative research projects or training.

Providing new or surplus equipment is another effective way of supporting institutes in developing countries. For example, FPL recently shipped two universal testing machines to the Central American Research Institute for Industry (ICAITI) in Guatemala. This nonprofit regional organization, established with support from the United Nations and now assisted by USAID, promotes regional industrial development through technical assistance, training, and applied research in support of both private and government initiatives. A third surplus universal testing machine and other surplus research equipment are now awaiting shipment to CORMADERA, a similar institute located in Quito, Ecuador.

Another way to support institutes in developing countries is by providing surplus library equipment, books, and periodicals. The FPL periodically ships these badly needed items to several institutes in developing countries.

These are some of the ways we are trying to provide direct support to selected institutes. Although many of the institutes represented at this meeting are engaged in similar activities, these efforts must be expanded.

Coordinating Forest Products Research

Although the IFP Program was established at FPL because of our dominant role in Forest Service forest products research efforts, the IFP Program also supports other Forest Service, university, and industry forest products research efforts. We also support the International Forestry Staff of the Forest Service in Washington, D.C., which has overall responsibility for international Forest Service activities.

One promising way of strengthening forest products internationally is through "twinning" or "networking" arrangements between organizations. For example, two organizations, most likely one in a developed country and one in a developing country, could agree to exchange staff or resources to strengthen one of the partners. Other possibilities would include a "pooling" of efforts to more effectively address problems of common interest (Burley 1987). Such networking could take place anywhere but may have more potential in the tropics where problems are often regional and resources scarce. Problems such as properties and uses of lesser known species, growth stresses, processing of difficult woods, alternative preservatives, and the need for harmonizing codes and standards would lend themselves to a unified effort.

IUFRO could play a major role in these networking or twinning possibilities. Important efforts are underway at this conference to facilitate these opportunities.

Exchanging Scientists

As discussed previously, FPL has a long history of providing research opportunities for visiting scientists. Many have been able to add to their experience through formal training at the University of Wisconsin or elsewhere. In our experience, these arrangements have been positive and beneficial to both parties, and we highly recommend scientist exchanges. The recent survey of wood technology research needs in Africa showed temporary exchange of research staff to be one of the most effective ways to strengthen the institutes surveyed (IUFRO 1989).

Recognizing the effectiveness of staff exchanges, we recently initiated the Visiting Scientist Program within the IFP Program to expand and strengthen our efforts. We are now recruiting scientists to come to FPL to work with our scientists on projects of mutual interest for 6 months or more.

We do expect visiting scientists to arrange their own financial support, but we are attempting to identify potential sources of support, particularly for prospective visitors from developing countries. We have had modest success and have had visiting scientists supported by the Food and Agriculture Organization (FAO), the USDA Cochran Middle Income Program, and soft money projects.

The IFP Program staff also provide assistance with other needs, such as housing, staff privileges, and medical insurance. We have also taken steps to provide special recognition for our visiting scientists and their contributions to the FPL research program.

We now have 24 visiting scientists at FPL, which is a typical number. Sixteen of these are from foreign institutions.

FPL and Forest Service training activities were expanded and strengthened this year with the initiation of the Forest Service Training Program on Tropical Woods. This program is supported by training funds attached to the recently passed Tropical Forestry Initiative. A portion of the funds is dedicated to forest products and is being managed by the IFP unit at FPL. The program is targeted for candidates from tropical countries who are expected to return home to jobs that are more applied in nature. Funds for round trip travel and limited support for living expenses while at the host institution are provided. Announcement and application forms have been sent, with a fall 1990 closing date. USDA Forest Service units have the lead in identifying candidates. This program will provide much needed impetus to support training at Forest Service research locations for candidates from tropical areas. The training level of the researcher was identified as the most important factor affecting research capabilities of institutes in developing countries (Bengston and Gregersen 1988).

FPL also supports the International Tropical Timber Organization (ITTO) Fellowship and Small Grants Program, which, among other things, supports short-term (1 year or less) visits to the FPL. This important program also supports FPL involvement in a project to identify all the common names of timbers.

Identifying Applicable Foreign Technologies

We are increasingly concerned in the United States about our lagging technological leadership in some areas. Many statistics can be cited to support that concern (National Science Foundation 1987, Council on Competitiveness 1988). At the same, we are increasingly aware that we should seek out foreign technology that could be applied in the United States. These trends apply in forestry and forestry research as well. Gregersen et al. (1989) conclude that U.S. gains from foreign forestry research are real and could be substantial. A role of the IFP Program is to help answer the following questions: Are new forestry-based technologies being developed in other countries that should be applied in the United States? Why have those technologies not been applied here? What research is needed to adapt them to our situation?

A common focus is the international competitiveness of countries and the role of their institutions in enhancing new technologies for their specific markets. However, we expect that advancement and application of new technologies will result from cooperative R&D on problems of common interest between countries.

Opportunities for regional approaches to solving problems would be particularly interesting in the tropics, as noted earlier. Collaborative efforts can enhance the availability of resources, distribute the risk, and facilitate the application of research results (Ronstadt and Kramer 1982).

The international forest products community has an obligation to enhance the competitiveness of wood as a material. However, its primary responsibility is to assure that forest resources are used wisely to promote good forest management. This is particularly true in the tropics. Despite the apparent opportunity to use tropical forests as a vehicle for development, they are often viewed as an unknown factor or even as an impediment. Research is needed to enhance the management of these forests for the economic benefit of the region while maintaining environmental quality.

CONCLUSION

The Forest Products Laboratory has increased its commitment to advance forest products internationally with the creation of the International Forest Products Program. This is a modest

effort to be sure, but it is real and unique. Through it, FPL efforts are dedicated to the advancement of wood in the family of materials.

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This paper was presented at the XIX IUFRO World Congress,
Montreal, Canada. August 1990.

Prepared July 1990

The Productivity of Forestry Research: Recent Experience from Five
US Industries and Its Implications for the Rest of the World

Abstract

This paper examines the empirical returns to public research in four forest products industries and the southern pine timber industry of the US, reviews the characteristics of differential success and failure, and then examines implications for the future--for the US, for developed country forestry research, and for developing country forestry research.

Forest products research has great but selective promise. The public is probably underinvested in forest products research, in the US and worldwide. It promises large future gains in social efficiency, as well as additional resource gains as it provides substitutes for timber harvests from lands with competing, non-timber uses. This is an important finding when placed in the context of the world forestry role in providing for global values having to do with climate change, biodiversity, and aesthetic resource demands.

The public is overinvested in timber management research in the US. This observation is also probably accurate for Canada and the Soviet Union, and perhaps for Japan, western Europe and most developing countries. Timber management research in all countries will become a better investment as the stocks of extensively managed timber are drawn down and stumpage prices rise. For the US South, this may mean the next ten to thirty years. For developing countries, this probably means as the institutions adjust to provide more secure tenure and as policymakers revise current policies with perverse secondary impacts on the forest.

The Productivity of Forestry Research: Recent Experience from Five US Industries and Its Implications for the Rest of the World¹

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Forestry receives great attention for its role in the global environment. With this attention, forestry research should also come under greater scrutiny. Can it produce enough trees to sequester carbon--and restrict global change? Can it help protect the natural forest habitats that sustain global biodiversity? Can it produce enough trees to satisfy human demands for wood and fiber? Can it do these things efficiently?

This paper is an initial inquiry into these questions. It examines research productivity in the forestry sector of the US economy for the period 1950-80. There is a broad literature surveying the efficiency of industrial research in general and agricultural research in particular. [See Ruttan (1980) for a survey.] There is also a broad literature on the impacts of technical change. Solow (1957) and Denison (1974) observe that research--through its product, technical change--has explained between seventy and eighty percent of the increase in US non-farm

1. The original draft of this paper was prepared while we were guests of I. Vertinsky and the Forest Economics and Policy Analysis Research Unit at the University of British Columbia in January 1989. The authors did the supporting empirical work at Duke university. FEPA and the USDA Forest Service provided financial support. M. Fullerton, T. Heaps, P. Pearse and especially A. Scott raised questions or contributed insight which improved both our analysis and our exposition. D. McKenney and J. Davis, Australian Centre for International Agricultural Research; and D. Brooks, US Forest Service reviewed and improved subsequent drafts.

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production in this century. Knutson and Tweeten (1979) observe that the marginal return on agricultural research and extension expenditures in the US has been greater than 35 percent annually since 1939. These observations confirm an historic record of research activities strongly improving aggregate US economic growth. Our question in this paper is whether this broad and general research experience has also held true for the forestry sector of the US economy--and whether it is likely to be true for global forestry research.

Our general approach is through a select series of empirical cases from the US. These cases include four examples from the forest products industries and one from the timber growth and management industry. The forest products examples are the softwood plywood industry, an industry which is generally thought to be an outstanding example of research success; the sawmill and woodpulp industries, two industries which largely define the forest products sector of the US economy; and the wood preservatives industry, an industry which provides the special example of product-altering (or quality-oriented) rather than process-altering research. The timber growth and management example is the southern pine industry. The southern pine industry has supported the most successful timber management and biological improvement research in North America. It is the basis for the most advanced timber production region of the US.

A glance ahead to our results shows great gains from forest products research, gains sometimes exceeding the best observed in agriculture. The success of southern pine growth and management research, however, is altogether more doubtful. Because southern pine research is thought to be a good example, this doubt encourages greater skepticism regarding the general performance of all less promising examples of timber management

research in other regions of the US. It also begs questions about the difference in performance between forest products research and timber management research and it raises the possibility that global environmental values like controlling climate change and maintaining biodiversity may be protected best by forest products research that decreases the demand for wood and fiber--rather than by direct timber growth and management research which has done a poorer job of increasing supply.

Our general inquiry was important for the US when we began in 1983 because American forestry research had not previously undergone a technical economic appraisal and because forestry was embarking on a period of unusually tight research budgets. Tight budgets beg careful justification of all expenditures. Furthermore, many developed countries shared this experience of tight budgets. Therefore, many developed country forestry institutions may also gain insight from our US observations.

Forestry has also become an exciting topic in economic development. An immense amount of money is being spent on forestry, including forestry research, in developing countries today.³ Much of this money originates with international lending agencies which generally require repayment regardless of the eventual success of local investments. Thus, while forestry research programs intend to produce great gains for the rural poor in many developing countries, they may promise increased and

3. Mergen *et al* (1988) estimate that global forestry research expenditures approximately doubled in ten years to \$1.024 billion (1980\$) in 1980. Expenditures in developing countries alone increased from \$79 million to \$198 million. More recently, the Consultative Group of International Agriculture Research institutions agreed in December 1988 to extend their agricultural activities by introducing three new forestry research networks, one each in Asia, Africa, and Latin America.

extended national indebtedness instead if these programs are chosen with less than the greatest care and best economic insight.

An important intention of this paper is to bring these public policy concerns together. The technical assessments of research in the five specific forest industries should permit reflection on the characteristics of other, greater and lesser, American successes of the recent past and they should provide some intuition with respect to the future of forestry research in the US. They should also provide initial justifiable extrapolations for the more general forestry research situations occurring around the world--regardless of the level of local economic development.

Forest Products Research

Our prototype evaluation for the forest products industries is the softwood plywood (SWPW) industry. Our SWPW analysis begins with the dual of the production function and with research as an explicit factor of production, transforms this production function to its counterpart supply function, and simultaneously estimates supply with demand. The dual uses input prices and costs rather than quantities. It is a data intensive approach relative to most agriculture research evaluations. It has the advantage, however, of improved accuracy and it also permits eventual calculations of both marginal and average returns to research.

Softwood Plywood Results

Table 1 repeats the non-linear two-stage least squares (NL2SLS) estimates for the SWPW demand and supply coefficients. The general statistical tests for these equations are all satisfactory. All

individual coefficients have the anticipated signs and all are significant at the ten percent level or better.

A separate statistical test rejects the hypothesis that the industry experienced other (disembodied) technical changes that are unexplained by either the public or the private R&D terms. This is not surprising. Public R&D, largely at the Forest Products Laboratory (FPL) of the US Forest Service, was extensive in the 1950-1980 period. The FPL participated in virtually all recognized SWFW technical change: new gluing techniques, experiments with little-used log species, and all new capital equipment experiments originating in the US. Private firms, in the SWFW case, concentrated on recognizing, receiving, modifying, and developing public research for the specific needs of individual plywood firms or plants.

The interesting terms for us, in table 1, are the last three terms in the production/supply equation.⁴ We assume that the continuing impacts of research on output have a Koyck distribution over time. The Koyck distribution starts at a peak and deteriorates at a rate determined by the coefficient for the lag term in table 1.

4. The subscripts following the R&D terms refer to the number of years following a research expenditure but preceding its initial R&D impact on output. Our estimation process for specifying this lag proceeds in three steps: (1) Obtain expert opinion: FPL scientists estimated a two year research-productivity lag before the initial R&D impact. (2) Obtain two-stage least-squares estimates for an index of SWFW technology as functions of public and private R&D each lagged from one to seven years: The statistically most satisfying estimate is for two years. (3) Use these two year research-productivity lags in the NL2SLS demand and supply estimates, but retest the final demand-supply specification for alternate R&D lags: Alternate R&D lags do not improve on the SWFW demand-supply estimates in table 1.

The elasticities deriving from the coefficients in table 1 are:

supply price	0.497	initial public R&D	0.0207
demand price	-2.703	long-run public R&D	0.19
labor output	0.2057	private R&D	<0.48
capital output	0.1263		

These elasticities are not inconsistent with related previous literature (McKillop *et al* 1980, Rockel and Buongiorno 1982). All but the private R&D elasticity are significant at the ten percent level or better.⁵

The market equilibrium price and quantity and the supply price elasticity explain industry production prior to the public research investment. The public R&D elasticity, the two-year research-productivity lag, the subsequent Koyck distribution of research impacts, and the lag coefficient explaining the decline in these impacts over time, altogether determine the position of the new industry supply curve at any time after the R&D injection. The area between the original supply curve and the new supply curve, and to the left of market equilibrium, measures the gross benefit from public R&D.

The first column of table 2 shows various final measures of these gross social benefits of public SWPW research. The net present value (NPV) estimates show that primary producers and their higher level industrial processors (consumers) share almost equally in these research benefits.

5. Direct evidence of private expenditures is unavailable. Therefore, we use a proxy for private R&D expenditures and the output elasticity of private R&D must be derived as a residual. (Its upper bound is one minus the other output elasticities.)

The large producer gains cause us to inquire about the public presence in this research effort. The competitive nature of the industry, and the non-exclusive nature of many SWFW research products, suggest that the individual firm's only incentive is the payoff the firm captures before its competitors adopt the same or similar new technologies. This is probably the payoff of the first two years. The annual flows of research benefits and costs, however, indicate that the average firm conducting independent research would not have recovered its research costs in any of the first eighteen years of our analysis.⁶ Thus, without a public presence, there would probably have been little research and little gain, for either producers or consumers.

The value of the marginal product (VMP) and the rate of return estimates further display the efficiency of public SWFW research. The short-run VMP is comparable to those found in agriculture and it shows that additional SWFW research investments would have returned more than their costs. The long-run VMP and the marginal internal rate of return (MIRR) are much greater than usually found in agriculture--perhaps because the initial SWFW research investments were small, or because the SWFW research-productivity lags were so short; therefore, the final research benefits are discounted less. The short-run and long-run VMPs and the MIRR all indicate that additional net social gains would have been available from even greater investments in SWFW research.⁷

6. There are approximately eighty firms in SIC 2436. The four largest shared approximately 38 percent of the market in 1978.

7. Sensitivity tests do not alter our confidence in these results. We examined alternative private R&D costs and discount rates. We also simulated the impact of differential Southern and Northwestern wage rates and we examined the different results that would obtain with exogenous estimates of the relevant price elasticities. The latter results show

Research in Other Forest Product Industries

The sawmill analysis furnishes most satisfactory statistical results--on the supply/production and the demand equations and on all coefficients in both equations. The supply and demand price elasticities, 0.34 and -0.60 respectively, are significant at the one and ten percent levels respectively. Both are consistent with previous literature (Robinson 1974, Adams and Haynes 1980, Lewandrowski 1989). The long-run public research output elasticity of 0.93 is significant at the five percent level. The research-implementation lag is a notable five years in the sawmill case. This longer lag is probably due to the large number, small size and diffuse nature of firms in the US sawmill industry (17,000 in 1950, 6,800 in 1980).

Average returns to public research in this industry fall in the range of 17-50 percent annually for consumers and 13-49 percent for society as a whole--depending on our estimates for the private implementation costs of new technologies. Producers are net losers. This means that, for producers, decreased production costs are largely passed on as lower consumer prices, causing producer revenue losses that cannot be offset by gains from increased outputs. It also means that sawmill managers have little incentive to invest in research and that the social gains from sawmill research would not be forthcoming if we relied on private industrial research. Marginal returns fall between five and 32 percent annually. This probably equals or exceeds the social opportunity cost of capital and it means that socially justifiable

that the magnitude of our SWPW results is not due to our improvements in the standard analytical approach.

sawmill research investments were at least as great as, and perhaps greater than, the historic 1950-80 investment level.⁸

The woodpulp analysis provides satisfying supply results but a problem for demand. Statistical tests on both the woodpulp supply/production equation and on its individual terms are satisfactory. The supply price elasticity of 1.09 is significant at the one percent level and the long-run public research output elasticity of 0.32 is significant at the ten percent level. Our econometric estimation of woodpulp demand is unconvincing, however, and perhaps a constant coefficient equation form would better explain the woodpulp-consuming paper industry. Our analytical solution is to employ our supply elasticities, together with an assumption of inelastic demand. Inelastic demand is consistent with both prior woodpulp literature (Guthrie 1972, Gilless and Buongiorno 1987) and more casual observations of the high fixed cost nature of the paper industry.

Average returns to public woodpulp research are 33 percent annually for consumers and fifteen percent for society as a whole. Producer gains are negative, as they must be in an industry with perfectly inelastic demand. Marginal returns are negative, indicating overinvestment in woodpulp research.

8. There is an argument that Swedish sawmill research produced a substantial positive spillover to American sawmills. If this spillover were statistically significant, then it would cause large error terms in our equations and an unsatisfactory coefficient of determination. Yet the coefficient of determination is an acceptable 0.67. Furthermore, if Swedish research productivity had a regular effect over time, then it would argue for a positive-signed term for disembodied technical change. Yet preliminary supply regressions with terms for disembodied technical change were less satisfactory in general and the coefficient on disembodied technical change both had the wrong sign and was statistically insignificant. Thus, we reject the argument for Swedish, or other international, research impacts on the US sawmill industry.

It turns out, however, that some woodpulp research dealt with environmental residuals. This research is of the product-altering, rather than the cost-reducing variety. Therefore, our measures of economic return do not reflect its benefits. This means that our average and marginal returns are lower bound estimates for the true measures.

Higher government authority mandated some 1970s research on energy-saving and pollution-reducing pulping processes. Pursuit of this research was contrary to the professional judgment of FPL scientists regarding its technical and economic feasibility and this research probably would not have been conducted in the absence of political intervention. The average and marginal returns to all remaining woodpulp research for the thirty-year period would have been higher. This is a second reason why our woodpulp results are lower bound estimates for the performance of FPL scientists and managers.

The wood preservatives analysis is also problematic. Our demand specification is statistically significant but the supply/production equation is less reliable. The demand price elasticity of -1.62 is significant at the one percent level. The supply price elasticity of 0.47 is insignificant. (There is no comparable econometric wood preservatives literature.) The R&D coefficients have the correct signs but only the private R&D coefficient is significant. The insignificant public coefficient may be due to the large investment in FPL research designed to reduce the petroleum-based environmental residuals associated with wood preservatives. Public research cost data include this investment but our output measure does not reflect their research products. The resulting partial cost-output mismatch may explain the statistical insignificance.

Nevertheless, we proceed on the confidence of the correct sign on the public coefficient (as is common in the research evaluation literature where statistical insignificance is the norm). The long-run public research output elasticity is 0.274. The average social return on public wood preservatives research may be as great as 293 percent annually. (Rates of return to consumers and producers are indeterminate because their time streams change signs several times.) Marginal social returns are negative, indicating either overinvestment or significant benefits in unmeasured product-altering wood preservatives research. Removing the costs of product-altering and environmental research would raise the marginal returns, perhaps to the positive range where they would also remove the question of overinvestment.

Comparative Results

Table 2 summarizes the similarities and differences in research production across the four forest products industries. The first summary observation is that public research investment was socially justifiable at some level in all four industries. That is, there were substantial net social gains from public research in all four. Yet:

~ The benefits of research would be spread too thinly among eighty establishments to sustain much private research investment in SWFW. Research benefits would be spread even more thinly among 6,800 or more sawmill firms. Indeed, the sawmill industry conducts virtually no private research of its own.

~ Inelastic demands in sawmills and woodpulp indicate that these industries pass most of their research gains to consumers. One reason why concentrated industries, like the woodpulp-consuming

paper industry, might vertically integrate is to absorb those consumer benefits.

~ The producers of wood preservatives and woodpulp cannot capture the benefits of those research improvements that decrease the non-market environmental residuals occurring in the production process.

In sum, all four industries can justify public research at some level on the basis of the resulting consumer and net social benefits. The minimal (often even negative) and intermittent producer benefits, the inability to establish lasting proprietary rights to these benefits, and the unlikelihood of sharing research costs across firms make large private producer investments in research unlikely in these industries. (These conclusions are all insensitive to reasonable adjustments in either private research implementation costs or the social discount rate.)

The generalized determinants of research performance are unclear. The results from these four industries suggest that neither firm size nor market power are correlated with public forest products research success. Average returns are greatest in SWPW and wood preservatives, which are the middle industries with respect to firm size and market power. The small size of the research programs in SWPW and woodpulp, the long research-implementation lag in the diffuse sawmill industry, the absence of unaccounted product-quality benefits in our benefit measures for wood preservatives and perhaps woodpulp, and ill-conceived political encouragement of some woodpulp research all appear to be more important explanatory factors of research performance than either firm size or market power.

In conclusion, public research performance in these four industries for the period 1950-1980 ranged from adequate to superior. It brought social gains that were often greater than those usually anticipated for marginal private investments, comparable to (if more variable than) the 35-110 percent average returns in Ruttan's (1980) survey of public agricultural research investments, and substantially in excess of either (negative returns for) public investments for non-industrial private forest incentives (Boyd and Hyde 1989 ch. 3) or (small positive returns for) public forest timber management (Repetto 1988, Boyd and Hyde 1989 ch. 8). These comparative observations are implicit compliments for the forest products research managers of the 1950-80 period of our analyses and they should encourage the research managers of today to sustain their best judgments.

Timber Growth and Management Research

Evaluating timber growth and management research poses new problems unfamiliar in either agriculture or forest products research. First, forest landowners, unlike SWPW millowners for example, are not a homogeneous group, all with similar production functions. Rather, the classes of public, industrial, and non-industrial private (NIPF) landowners may each have different management objectives and only industrial landowners may have strict timber production objectives. This restricts our confidence in the profit maximization assumption underlying any specification of an aggregate production function.

Furthermore, there are two new difficulties for direct estimates of stumpage research shifters: (1) The long and uncertain lags between initial research and eventual productivity surely obscure statistical

reliability. (2) Less frequent data (Forest inventories are generally collected in ten year cycles.) and data that cannot segregate growing stock from final output put timber management research evaluation at additional disadvantages relative to either agriculture or forest products research evaluation.

This causes us to reflect further about the dynamics of timber production research. Our southern pine production relationship explains standing inventory as a function of various capital and labor inputs and a time shifter. The time shifter is a proxy for disembodied technical change. It includes research-induced inventory shifts and it may include some regular increases in productivity due to unspecified causes other than research.

Stumpage supply is a second function of the various inputs to supply, including inventory. The time shifter in the previous production function becomes a supply shifter. Supply is more complex, however, because southern pine production is a joint input for two supply functions, solidwood and pulpwood. Therefore, southern pine research has an impact on two products and we must simultaneously estimate supply and demand for both products, each with a standing forest inventory term.

Limited data restrict the empirical analysis of inventory production. There are twelve state and four periodic inventory observations between 1948 and 1984. The inventory observations, n , first must be corrected to reflect (a) inventory plus removals in the years between successive observations and (b) constant measures of inventory quality for all four periodic observations. There are no observations of the standard capital and labor inputs to production, but there are observations on ownership type O_k and management intensity m which

coincide with each state inventory observation. These act as proxies for capital and labor intensity. For example, plantations on industrial lands are more input intensive than mixed oak-pine stands on NIPF lands. Finally, biological and site quality observations B_i , collected as part of the periodic observations on forest inventories, control for exogenous effects like regeneration preferences, weather and improvements in soil quality. The aggregate production analysis also adjusts over time for changes in the land area of the southern pine forest.

The general functional form is

$$V = a_i c_i c_n B_i^{\alpha} \exp(\beta_n n) \left(\prod_{k=1}^K d_k \right) \left(\prod_{m=1}^M \gamma_m \right) n$$

where the a_i , β_n , and γ_m are unknown parameters, and n is the error term.

The statistical estimations are satisfying. The signs on all coefficients in the basic equation support intuition and fourteen of seventeen coefficients are statistically significant. An R^2 of 0.99 indicates that the independent variables explain virtually the entire variation in the dependent variable. Most important for our analysis, the technical change shifters are all significant at the five percent level or better (for the basic equation and for various specialized equations reflecting specific management-ownership combinations).

In sum, we have confidence in the ability of the time coefficients to explain shifts in production. They explain approximately seven, fourteen, and six percent shifts in successive (approximately decennial) inventory periods from 1948 to 1984. The total increase is 27 percent for the full period, or about 0.7 percent annually, compounded.⁹ This

9. Conversations with university forestry researchers and forest industry research administrators suggest that they look for volume

may be a generous estimate of research-induced productivity shifts because it includes both 1) non-research-induced shifts and 2) movements along as well as shifts in the production function. It also may be conservative, however, because our approach controls for shifts in management type that may be partially research induced. Sensitivity tests for variation in the estimated production shift protect against these biases affecting our general conclusions.

Table 3 repeats the results of our three-stage least-squares (3SLS) demand and supply estimates. (There is no previous econometric evidence of the joint solidwood-pulpwood market for southern pine stumpage.) The general statistical tests for the four equations are satisfactory.¹⁰ The inventory coefficients imply solidwood and pulpwood elasticities of 0.391 and 1.201, respectively.

Our measure of gross research benefits follows a derivation by Hertford and Schmitz (1977) that relies on our estimate of research-induced inventory shifts and the various demand and supply elasticities. Table 4 shows the *undiscounted gross* research benefits accruing to consumers, producers, and all society in both the pulpwood and solidwood markets for the range of research-induced inventory shifts between 0.5 and 1.0 percent annually. Total social benefit estimates are sensitive to this inventory shift but they are insensitive to large variations in the demand and supply elasticities.

increases of twenty percent over a southern pine timber rotation of 25-40 years. Their expectations are consistent with our observations.

10. The interesting observation that pulpwood is a substitute in solidwood supply, yet solidwood is a complement in pulpwood supply, supports an earlier observation for Sweden by Johansson and Lofgren (1985).

Total benefits are small, \$40-80 million for the full thirty-year period from 1950 to 1980. Consumers (loggers, millowners, and final product consumers) gain more than stumpage producers. This distributive result is similar to the experience of agriculture, sawmills, and woodpulp where research benefits quickly pass to higher level producers and final consumers in the form of lower prices. The emphasis on consumer gains encourages a public role in southern pine research. Solidwood producers gain only minimally and pulpwood producers are gross losers as they pass more than their full gains on to consumers. This conclusion anticipates the more general observations that industrial landowners seem to be reducing their research budgets and relying relatively more heavily on NIPF producers to supply their mills. (NIPF lands provide approximately seventy percent of annual southern pine harvests.) It also anticipates that even those NIPF landowners with clear timber management objectives have little private incentive to encourage research in new timber management technologies.

The Efficiency Benefits of Southern Pine Research

Measures of efficiency gains also require knowledge of the R&D expenditures on timber growth and management research. Historic budget data are unavailable for many of the institutions involved in southern pine research. Therefore, we began with known US Forest Service budgets for the Southern and Southeastern Forest Experiment Stations--reduced by those research expenditure categories not clearly and fully associated with southern pine growth and management (e.g., forest recreation). We can extrapolate expenditure series for the other research participants--for state and university research, industry research, and forestry extension--from occasional direct evidence over the years, and from

periodic references to the size of these expenditure categories relative to Forest Service expenditures. We disregard all research expenditures prior to 1935, the uncertain level of expenditures by university/industry cooperatives, and the uncertain contribution of general forestry education to improving southern pine yields--all in the name of conservative total cost estimates. Conservative cost estimates, together with generous benefit estimates, will provide a confident upper bound for observations on the efficiency of timber management research.

The research-productivity lag poses an insurmountable estimation problem for timber growth and management. Our alternative is to examine a full range of hypothetical lags. We consider lags from zero to twenty years in five year increments and compare costs and benefits in all five cases. We begin with cost cohorts representing accumulations of the annual expenditures that induce our measured 1950-1980 southern pine research benefits. The first cost cohort is 1935-1960, the second is 1935-1965, etc. The first cohort is the smallest research cost accumulation but it implies a maximum twenty-year lag before its last research expenditures (1960) begin to affect harvests (1980).

Table 5 shows the results. Net benefits are negative for all but the single most extreme case. Even then they remain small at an accumulated \$29 million for the entire thirty-year period of research impacts--or an average of only \$80,000 per state per year. The second part of table 5 provides an additional check for the robustness of these results by comparing only the Forest Service share of all southern pine research costs with our total benefit estimates. Net benefits remain negative for the most reasonable cases of positive social discount rates and moderate research-productivity lags.

In conclusion, annual *physical* research gains of 0.7 percent may satisfy industrial researchers but the social efficiency of these gains is uninspiring at best for southern pine growth and management. This conclusion holds for the sum of a broad collection of research activities. These results do not preclude the possibility that select and more specific research activities, perhaps various nursery-oriented research activities or weed control research, may display more satisfying results.¹¹ Nevertheless, because southern pine is generally considered the best example of timber management research success, it is probably unnecessary to examine other broad regional cases or forest types. We anticipate similar, or poorer, results for them.¹²

Reflections on Timber Growth and Management Research

Can we believe this empirical observation of generally poor economic performance for southern pine management research? What explains it: perhaps low long-run timber production costs? Low production costs would

11. Consider the economic literature on gains from nursery management and improved seed stock (Davis 1967, Porterfield 1974, Westgate 1986, Williams and deSteiguer 1990). Much of it anticipates that microeconomic speculations can transmit into aggregate, sector-wide gains, particularly in the southern pine region. This transmission may not hold without sharply declining stumpage price effects and resulting negative net revenues. The potential of herbaceous weed control research is better documented (Huang and Teeter 1990, Warren 1990). In sum, the literature raises the spectre of possible economic gains from some timber growth and management research.

12. We followed this examination of economic efficiency with an inquiry into the redistributive merit of southern pine research. We used the US Forest Service's input-output model (IMPLAN, Alward and Lofting 1990) to examine wage and employment impacts in the forestry sector and in the full economy for three important forestry regions within the South. The important policy shifter in these analyses is a research-induced timber productivity increase of three percent (approximately 0.7% annually) for a normal 2-5 year cycle of business expansion. The resulting wage and employment shifts are never large and they are always unimportant for the lowest wage industries.

leave few opportunities for cost-saving production gains, therefore little inducement for research and few final opportunities for introducing technological improvements.

Most timber production research has been of the land-saving or capital-(investment time)-saving variety. This is a reasonable outgrowth of what are often natural transfers from agriculture research. It is also reasonable because land and capital, not labor, are the predominant physical inputs. Land and capital have not been economically scarce inputs in forestry, however, and they will not become scarce inputs so long as there are stands of old growth timber, abandoned old fields reverting to timber, and remaining timber harvest opportunities on less accessible sites.

These observations are consistent with the frontier hypothesis for development of the forestry sector of the US economy. Even among southern industrial forests, less than forty percent are actively managed plantations (USDA Forest Service 1988). Therefore, it should not be a surprising observation that current stumpage prices do not cover the costs of active silvicultural investments for all the acres from which timber is harvested. Removing the bounty of naturally occurring timber, however, must eventually cause stumpage supplies to decrease.

The available empirical evidence suggests that this transition from frontier to developed forest economy has been going on for some time. Relative roundwood prices probably have been rising for over a century (Ruttan and Callahan 1962, Barnett and Morse 1963, Manthy 1978).¹³ We might reasonably anticipate that they will continue to rise gradually

13. This experience of rising relative prices for such a long period of time is unique for lumber, and perhaps timber, among all primary resources (Barnett and Morse 1963, Manthy 1978).

until they finally equal the full long-run (timber rotation) costs of active silvicultural management on most forestlands. [There will always be some marginal lands contributing some share of all harvests from unmanaged, naturally occurring, low opportunity cost timber (Sedjo and Lyon 1990).]

Nevertheless, relative prices cannot continue increasing indefinitely and there is some expectation that the long-run upward price trend will deteriorate within the next ten to thirty years (Berck 1978, Libecap and Johnson 1978, Lyon 1981). It may have tapered off already in the South (Dutrow *et al* 1982, Cabbage and Davis 1986). Prices will eventually attain the level of full active silvicultural production costs on more acres before they cease to increase any further (in the absence of unanticipated shifts in demand). This means that the future may be more promising for southern pine research investments. In sum, the prior poor performance of southern pine research in the aggregate surely urges the utmost care in choosing which timber growth and management research budgets to continue supporting. Furthermore, it encourages greater care and greater reluctance for support of timber growth and management research for the other species and other forest types which probably have an even less distinguished history of research productivity than southern pine.

Final Reflections and Broader Policy Implications

This final section reflects on the meaning of our empirical results for the future of forestry research in the US and draws implications from this American experience for both the developed and the developing countries of the rest of the world. We speculate that available forest

inventories and final consumer markets are critical indicators of world research policy implications different from those for the US.

Policy Implications for American Forestry Research

Our analyses support the public policy advice to concentrate forestry research on forest products and to fund timber growth and management research only most lightly and most carefully. Concerns for equity; including laborers, small landowners, and rural development; do not alter this recommendation.

Forest products research has an entirely more satisfying past than timber management research but a past that still encourages cautious decisions regarding both justifiable public roles and future budget allocations. Our analyses justify a public role in research for each forest products industry we examined. Careful review, however, shows that the specific justification varies from industry to industry and that there is no reason to anticipate that the general justification for a public role is universal across all forest products industries. Future investments in these and other forest products industries require prior inquiry into the nature of each industry's production costs, its research-productivity lag, the likelihood of research adoption, and the industry's market concentration, in order to determine the independent justification for a public research role in that industry.

Furthermore, successful research performance in the past is not a necessary indicator of outstanding future performance. For example, SWPW research was a great success between 1950 and 1980 but the SWPW industry has been partially replaced by the newer products of the structural particleboard industry. The growing market share of the latter industry

(and declining share of the former) suggests a greater future potential for particleboard research.

Experience also recommends caution in adjusting research budgets to short-term political perceptions rather than longer-term market signals. For example, higher level government directives responding to both energy and environmental concerns in the 1970s failed to produce new cost-reducing technologies for the woodpulp industry. These directives did, however, divert Forest Products Laboratory research resources that had a previous history of more socially efficient production.

Nevertheless, our summary statement for forest products research is that previous research, on the whole, has been socially rewarding. We anticipate the same for the future, both in narrow and measurable economic efficiency terms and in broader social welfare terms. For example, we anticipate successful product-altering research, like some research in the woodpulp and wood preservatives industries which improves environmental quality. The benefits of product-altering environmental research, of course, fail to appear in those economic accounts of research and technical change that can only measure process innovation.

We also anticipate that forest products research and new technologies save on wood utilization and, therefore, save standing timber and forestland for other, often non-market, land uses. US Forest Service calculations, for example, suggest that the truss frame construction technology may save a volume of wood greater than annual programmed harvests on all lands proposed for wilderness withdrawal.¹⁴

14. Specifically, the 28.6 million acres proposed for wilderness withdrawal in RARE II. (US Forest Service calculations provided by H.G. Wahlgren, February 15, 1989.)

Indeed, the truss framing example nicely addresses another important question for forest policy. Forest land use, with competing industrial, recreational and environmental demands, is one of the most important natural resource issues of our time. Apparently, forest products research is a more elastic substitute for forest land than timber management research. Forest products research is also a better public investment than public timber management itself. Therefore, investing in forest products research may be one of the better ways to reduce the land use conflict and to save forests for competing non-timber uses.

This observation gains significance as we reflect on its implications for the important global issues of climate change and biological diversity. Forests provide the habitat for many endangered species and trees sequester the carbon that controls climate change. Apparently, forest products research, by decreasing the demand for wood and wood fiber, contributes more than timber management research to protecting the forest and these global values. We anticipate that biological forestry research may be better advised to concentrate on identifying critical species and habitat and improving their management.

Various other researchers find approximately two percent annual rates of technical change across the forest product industries. They also observe a labor-saving bias in technical change (Kendrick 1961, Stier, 1980, Greber and White 1982, Buongiorno and Lu 1989). Therefore, the rates of land- and capital-saving change are somewhat less. Even land- and capital-saving rates of 1.5 percent, however, are more than double the 0.7 percent average annual rate we observe for southern pine. This means that, for a constant output of forest products, the uses of roundwood and capital facilities as inputs decline at the rate of 1.5

percent annually. It also means that, in 48 years, research and technical change will permit the forest product industries to consume just one-half their current level of all roundwood inputs while producing the same volume of final product. In contrast, it takes timber management research 103 years to double the volume of southern pine harvests. It takes even longer for timber management research in other US species and it would take longer for southern pine if southern pine research investments were reduced to a lower, more socially efficient level.

Implications for Forestry Research in the Rest of the World

These US experiences are only partially transferable. We must examine the specific market situations and policy incentives in other countries, for both forest products and timber growth and management, and contrast them with US markets and incentives before we can determine which conclusions transfer from the US forestry research experience to the rest of the world. We might anticipate that our general encouragement of forest products research does transfer, with emphasis on products with large markets. General conclusions for timber management research are more difficult. There may be four classes of cases, two in developed countries and two in developing countries, depending on local market and incentive conditions for timber and forestland in each country.

Developed countries: Forest products research opportunities for developed countries are comparable to those for the US. The products are similar and the markets are generally well-developed. Price-induced

research and technical change may generally payoff at a high rate of social return, much as it does in the US.

The timber inventory and forest land situations may distinguish two developed country alternatives for timber management research. Canada and the Soviet Union are countries like the US, countries with large extensive margins of timberland. Indeed, Canadian and Soviet forest inventories are subject to a lower average level of active silvicultural management than US forest inventories. This extensive resource holds down stumpage values in Canada and the Soviet Union. Therefore, we expect that land and timber are relatively less scarce factors of production than labor and capital facilities, that the economy-wide incentives inducing labor- and capital-saving research are greater than the incentives inducing land- and timber-saving research, and that technical change can proceed only at a slow rate in the timber management industry. Forestland development follows the frontier hypothesis of economic growth. Like the US, there may be select and scattered timber management research opportunities in Canada and the Soviet Union, but general timber management research probably is not a highly productive activity in these countries.

This conclusion is consistent with Sedjo and Lyon's (1990) finding that, in an integrated world market, intensive forestry would be practiced on only the very best sites. Sedjo and Lyon find that, in the US South, only modest levels of investment in regeneration are optimal. In much of Canada, optimal management levels are low cost and very extensive.

Japan and the developed countries of western Europe may suggest a different case for timber management research. These countries arguably

possess no substantial extensive land margin supporting a natural bounty of timber and there are few old fields freely reverting to forests. In this case, the impact of wood and wood fiber imports from North America, the Soviet Union and tropical countries with a forest frontier will determine the viability of Japanese and western European timber management research.

The impact of imports will be *important* for timber management research if imports are large enough to have an impact on domestic stumpage prices. This means that imports will have kept Japanese and western European stumpage from achieving a level of scarcity comparable to the relative scarcity of substitute resources. Therefore, the extensive timber frontier in other parts of the world is also an economically important frontier for Japan and western Europe. In this case, timber management research is not a socially attractive investment, even in Japan and western Europe. It will become more attractive as it becomes a better investment in the exporting countries.

Alternatively, the impact of wood and wood fiber imports will be *unimportant* for timber management research if relative Japanese and European stumpage prices are changing at a rate comparable with the rate for substitute resources in these economies. In this latter case, timber management would be a developed industry in Japan and western Europe and the price incentives for timber management research and technical change would be fully operative and comparable with those for the rest of the economy. Timber management research would be fully as attractive as forest products research in this case.¹⁵

15. Japan's log imports from North America, the Soviet Union and the tropics were 62 percent of total domestic consumption in 1987. Japan's imports of roundwood equivalents from the same regions were 71 percent of total domestic consumption in 1987. The comparable western European

Determination of the correct alternative explanation for developed countries like Japan and those in western Europe must wait for (a) inference from assessments of regional relative stumpage price trends or (b) direct evidence from individual timber management research appraisals comparable to our assessment of southern pine research in the US.

Developing countries: There is less processing and the markets for processed wood and fiber products are less extensive in the developing countries than in the US. Therefore, the scope for forest products research in general is smaller in most developing countries than it is in the US. The result may be fewer forest product research opportunities, but those research opportunities that do exist probably offer the same high social rewards that forest products research offers in the US and other developed countries.

The logging industry may be a particularly good candidate for developing country forest products research. Our southern pine results and our extrapolations from them to other species and forest types and other parts of the world say nothing about logging research investments. Standing timber priced on the stump (stumpage) is our physical market measure in the southern pine case. Logging is the next higher step in the production process. Logging technologies are more labor- and capital equipment-intensive and less land- and resource-intensive than timber

import proportion from the same regions was, perhaps, one-third as great (J. Vincent, Michigan State University, personal communication, March 29, 1990). These data suggest the hypothesis that Japan may fall in the first category where imports from regions with forest frontiers are deterrents to price-induced technical change and economically viable timber management research. They also suggest the hypothesis that western Europe falls in the second category, and timber management research may be economically viable. We emphasize, however, that these data are weak evidence and that the Japan and western European cases beg further inquiry.

growing and management. Therefore, they are similar to forest products technologies as likely candidates for productive research investments.

Most modern logging technologies were developed in economically advanced countries where labor is scarcer relative to capital equipment. This relative difference in factor endowments may suggest opportunities in many developing countries for modern, yet relatively more labor-intensive, logging technologies. The absence of good roads and the range of topographic conditions across all developing country harvesting situations suggests further opportunity for either capital specialization or greater reliance on labor's versatility. In any case, logging technologies specially adapted to developing country conditions may be a rewarding forest products research opportunity.¹⁶

The market for wood as a domestic fuel for heating and cooking is an additional large market, therefore an additional forest products research opportunity, that is not so important in most developed countries. This market provides incentives for additional wood processing technologies that may be less important in developed countries. The obvious examples are charcoal research and research on improved stoves. The latter is a well-known recent success in many developing countries. Research to improve the efficiency of fuelwood consumption may have additional appeal from an equity perspective. The poorest households spend the largest household budget shares and have the highest income elasticities for fuelwood and its substitutes (Hyde 1991).

Timber management research, as always, is more problematic. Many developing countries possess extensive stands of mature forest. The depths of the Amazon and Congo watersheds and the northeast of Thailand

16. J. Douglas of the World Bank alerted us to this point. Laarman (1978) provides analysis and empirical evidence for the Philippines.

are examples. These forests compare with the US, Canadian and Soviet case. A large extensive margin of forestland holds timber production costs low. Timber is not scarce relative to other factors of production and there is little economic incentive for timber management research. Timber management research in this case will have little social payoff.

Other developing countries may have less extensive forest resources but insecure tenurial rights for their remaining timber resources. The arid lands of India, the nationalized forests of Nepal and the uplands of the Philippines are examples (Hyde 1991). Insecure tenure encourages immediate local resource-consuming self-interests and removes any incentive for long-term resource management. Therefore, it dissipates all economic incentives associated with the basic timber and forestland resources and causes resource depletion. In this case, there can be no price incentive for timber management research and timber management research is a misuse of public funds.

Finally, there are numerous cases of unintended but perverse policy spillovers to the forest resource. Binswanger (1989), for example, identifies a long list of macroeconomic policies and policies directed at rewarding other sectors; e.g., agriculture, livestock, mining; that encourage Amazonia's conversion to non-forest uses. Boyd *et al* (1991) measure the impacts of a similar list for the Philippines. These policy spillovers come to rest on the forest resource because forests are generally a residual land use often without a specialized market-oriented constituency. These policies are equivalent to downward relative timber price shifts. They act as further disincentives for timber management research.

These three; a large margin of extensive timber management, insecure resource tenure, and perverse policy spillovers; are important cases in very many developing countries. They are dissimilar with agriculture and they cause dissimilarity with the successful agriculture research experiences which are well-known for many developing countries. Therefore, direct comparisons with agriculture research in these countries, or with timber management research in developed countries, only conceal the important production relationships and the real policy issues. Unreasoned arguments to the contrary are distressing.

It seems to us that the altogether different issues of insecure resource tenure and perverse policy spillovers are the necessary first issues of policy inquiry in these cases. The products of timber management research, whether the timber is for domestic or for market consumption, cannot be introduced successfully until these issues are dealt with better. Tenure and perverse policy spillovers from non-forestry sectors are the better initial target for public research investments.

This said, we must also recognize another, more satisfying, timber management research case in many developing countries. Tenure is secure on most agricultural land and we observe many farmers who recognize the personal benefits of tree crops. We also observe some successful commercial forest plantations. Economic incentives are fully operative for the subset of these tree crops and these commercial plantation species for which the natural forests on the extensive margin of land with insecure tenure are unsatisfactory substitutes. This is a small but increasing share of developing country timber resources. Acacia in Bangladesh may be an example (Byron 198). The economic incentive

exists, but the small overall size of these farm forests and commercial plantations suggests generally small returns to timber management research. This recommends timber management research concentrating on those few species with large and widespread markets, as well as minimum competition from species growing naturally on the extensive margin.

This recommendation is consistent with the more biological research orientations of Buckman (1988) and Davis *et al* (1988). Buckman also encourages forestry extension in these cases. Successful extension improves research benefits by decreasing the communication time between successful research and its implementation by the many small forest farmers.

As the natural forests are depleted, as institutions adjust to ensure secure tenure, and as policymakers reconsider perverse policy spillovers, then we can anticipate that this final case will become more characteristic of developing country timber management. Farm forestry and commercial plantation forestry will become more prominent and the economic and social incentives for timber management research will increase. This may, however, take some time in most developing countries. Our evidence argues that the time has not yet arrived in the southern pine region of the US. It probably has not yet arrived elsewhere in the US, in Canada or in the Soviet Union. Therefore, we must urge the greatest care in choosing timber management research activities, particularly as a widespread use of public funds in developing countries.

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Table 1: NL2SLS Estimates of SWPW Demand and Supply Coefficients

<u>demand</u>		<u>production/supply</u>	
intercept	8.8088** (3.8696)	labor	.2057** (.1125)
own price	-2.7034* (-.4901)	capital	.1263** (.0604)
construction wage	-0.6076*** (-.4205)	(private R&D) _{t-2}	.0660* (.0218)
cost of capital	.1263** (.0597)	(public R&D) _{t-2}	.0247** (.0131)
substitute (lumber) price	3.0603* (.4265)	lag	.8694* (.0378)
final product price	2.3583*** (1.5586)		
R ²			.9839
D-W			---
Durbin's h			.0270
degrees of freedom			22

Numbers in parenthesis are standard errors.

Asterisks refer to statistical significance in one-tailed tests:

* = 1%, ** = 5%, *** = 10%

All coefficients implicitly refer to year t except where otherwise indicated.

Table 2: Returns to Public Research Investments (1950-80) in Selected Forest Products Industries

	<u>softwood plywood</u>	<u>sawmills</u>	<u>woodpulp</u>	<u>wood preservatives</u>
NPV (consumers' surplus) ^c	\$1.32	38.97	\$.018	\$61.90
(producers's surplus) ^c	\$1.50	-17.56	-\$0.022	-\$68.29
(net economic benefit) ^c	\$2.84	25.96	\$.004	\$251.86
IRR on NPV (consumers' surplus)	326%	34%	33%	multiple solutions
(net economic benefit)	499%	28%	15%	293%
VMP (short run) ^a	\$12.49	----	----	----
VMP (long run) ^b	\$58.17	\$2.62	\$.44	\$.34
MIRR	299%	16%	<0	<0

a. In 1967\$

b. In 1967\$ discounted at 7%

c. In billions of 1967\$ discounted at 7%. Consumers' and producers' surpluses are each net of total research costs. Therefore, net economic benefit = net consumers' plus net producers' surpluses plus total research costs.

Table 3: 3SLS Estimates for Southern Pine Pulpwood and Solidwood Markets

pulpwood				solidwood			
<u>demand</u>		<u>supply</u>		<u>demand</u>		<u>supply</u>	
intercept	731,700 (570,600)	intercept	-776,000* (-181,100)	intercept	-1,645,000* (-501,900)	intercept	888,900* (168,800)
own price	-9,092** (-5,127)	own price	4,921** (19.53)	own price	-3,162** (-1,423)	own price	3,072* (374.1)
final good price	1,800 (6,387)	inventory	0.02246* (0.001260)	final good price	21,730* (6,943)	inventory	0.00648* (0.00167)
labor	304,300* (97,570)	solidwood price	491.1** (239.8)	labor	114,900** (50,730)	pulp/paper price	-11,280* (-1,694)
capital	-2,341,000* (-764,900)			capital	1,025,000** (731,400)		
lagged production	0.2265** (0.1004)			lagged production	0.7860* (0.1299)		
R ²	.869		.952		.938		.934
D-W	1.116		1.034				1.475
Durbins' h					0.821		
F	31.84*		171.89*		72.62*		122.65*
degrees of freedom	24		26		24		26

Numbers in parenthesis are standard errors

Asterisks refer to statistical significance: *=1%, **= 5%, ***= 10%

Table 4: *Gross Benefits, 1950-80, from Southern Pine Research (millions of 1967\$, undiscounted)

benefitting group	annual research-induced production shift					
	0.5%			1.0%		
	consumers	producers	total	consumers	producers	total
market						
solidwood	18.54	2.10	20.64	36.86	5.04	41.90
pulpwood	31.58	-11.53	20.05	63.03	-22.74	40.29

Table 5: Net Benefits, 1950-80, from Southern Pine Research (millions of 1967\$)

present net value, with full estimated costs						
social discount rate	0%		4%		7%	
research-induced production shift	0.5%	1.0%	0.5%	1.0%	0.5%	1.0%
cost cohort						
1935-1960	-15	29	-89	-13	-243	-121
1935-1965	-81	-38	-217	-141	-450	-328
1935-1970	-178	-135	-372	-292	-667	-546
1935-1975	-320	-276	-558	-482	-894	-773
1935-1980	-527	-483	-780	-705	-1,130	-1,008

present net value, with US Forest Service Southern and Southeastern Forest Experiment Stations' research expenditures only						
social discount rate	0%		4%		7%	
research-induced production shift	0.5%	1.0%	0.5%	1.0%	0.5%	1.0%
cost cohort						
1935-1960	16	60	-13	63	-96	26
1935-1965	-5	39	-53	23	-162	-40
1935-1970	-35	9	-101	-25	-229	-107
1935-1975	-67	-24	-144	-68	-281	-160
1935-1980	-102	-58	-181	-106	-321	-200

Strategic Planning in Public Forestry Research Organizations¹

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Introduction

What Is Strategic Research Planning?

Strategic research planning is concerned with shaping the nature and direction of a research organization (What is our mission? Where are we going?) and developing broad strategies for accomplishing the mission (How do we get there?). Successful strategic planning involves confronting difficult choices, setting broad priorities, envisioning the organization's future, and developing procedures to achieve that future (Pfeiffer et al. 1989). The time frame is long-term, 10 years or longer in some cases. Strategic planning is the responsibility of senior research management.

A distinction should be made between strategic planning and traditional long-range planning. Strategic planning:

- focuses on identifying, managing, and resolving issues;
- emphasizes assessment of the environment outside and inside the organization; and
- is concerned with the "vision of success" of a research organization and how to achieve it.

Long-range planning:

- focuses on achieving specified objectives of the organization;
- emphasizes management of the internal environment — the human, financial, and physical resources expected to be available to the organization; and
- tends to be based on historical projections and does not work well under changing external conditions.

Long-range planning has the flaw of focusing managers' attention on predicting rather than creating the future (Hanna 1985).

Why Is Strategic Planning Needed?

Uncertainty, complexity, and change characterize the external environment in which research organizations operate. Research managers need to respond quickly and effectively to changing circumstances. Strategic planning helps to define an overall sense of direction and purpose for a research organization, and thereby helps managers respond to change. Vihavainen (1987) notes

1. An earlier version of this paper appeared as a chapter in Gregersen et al. (1990). The author thanks Hans Gregersen, Allen Lundgren, and Barbara Weber for helpful comments on this paper.

that the dynamic and uncertain environment of research suggests that dynamic management systems — including strategic planning — are well suited for the management of research.

Several potential contributions of strategic planning may be identified, including:

Short-term benefits:

- raising awareness about the external environment
- improving the dialogue among managers on strategy
- improving the dialogue between managers and professional staff
- improving the dialogue between the research organization and its stakeholders
- building teamwork and planning expertise

Longer term benefits:

- providing direction, coherence, and unity to organizational efforts
- improving organizational performance
- stimulating forward thinking in the organization, especially among top managers

The last point is perhaps the most important contribution. Strategic planning is not an end in itself, but should help research managers *think* and *act* strategically. Successful research organizations have always been guided by strategic thought and action, and a strategic planning process can aid in developing this perspective.

A Strategic Planning Process

The approach used for strategic planning should be adapted to suit the nature and circumstances of the particular organization (Milne 1989). Strategic planning in a large corporation will differ in certain ways from strategic planning in a small, public research organization, e.g., in the size of the planning team, resources devoted to the planning effort, the amount of involvement from outside the organization. But the essence of strategic planning is a process of thinking that is largely independent of scale and is useful in all types of organizations (Goldsworthy 1987). As Espy (1986) notes, if an organization is large enough to work, it is large enough to plan.

This section provides a systematic approach to strategic research planning that can be adapted to the needs of a particular research organization, and implemented by existing personnel at reasonable cost and in a timely fashion. The following strategic planning process is adapted from Bryson (1988), Pfeiffer et al. (1989), and Barry (1986), and is depicted in Figure 1. It is similar to the process used in recent nationwide and regional strategic planning efforts of USDA Forest Service research (Sesco and Bey 1989, Alig 1989).² The planning process involves eight major steps:

1. Initiating and agreeing on a strategic planning process
2. Identifying and clarifying organizational mandates
3. Conducting a stakeholder analysis
4. Developing a mission statement

2. See Goldsworthy (1987), Rocheteau (1987), Milne (1989) and Collion (1989) for other descriptions of strategic planning processes for public research organizations and research systems.

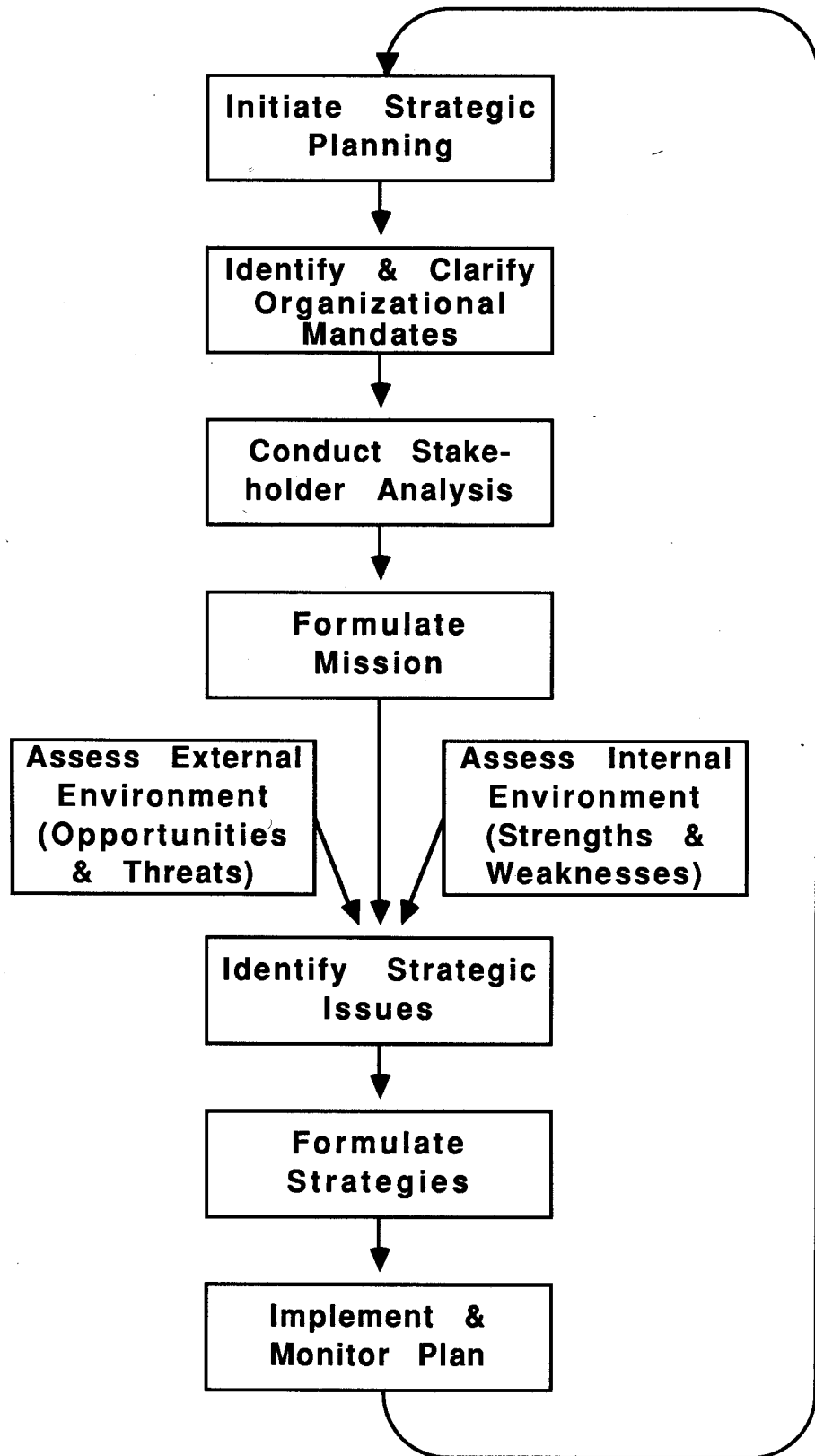


Figure 1. A strategic planning process.

Source: Adapted from Bryson (1988), Pfeiffer et al. (1989), and Barry (1986).

5. Assessing the external and internal environments
6. Identifying strategic issues
7. Formulating strategies to manage strategic issues
8. Implementing and monitoring the strategic plan

The following sections describe these steps.

1. Initiating and Agreeing on a Strategic Planning Process

The first step in strategic planning is to reach initial agreement about the nature, purpose, and process of strategic planning. A strategic planning team should be formed to address the following important preliminary questions: Who should be involved in the effort (individuals and organizations)? Who will be on the strategic planning team? Who will oversee the effort? What are the potential benefits to the organization of strategic planning? What resources are needed to proceed with the effort? What are the desired outcomes? What specific steps should be followed? What should be the form and timing of reports?

Key research decision makers should be included on the planning team, and perhaps some representatives of important external “stakeholder” groups (e.g., representatives from forest-based industries, conservation groups, government agencies that use research results). On the other hand, research managers may decide not to involve external stakeholders initially — outside involvement will complicate the process. Representative team leaders and scientists should also be involved from the beginning. The planning team should include one or more highly intuitive individuals, who tend to be the most innovative and insightful in strategic thinking and decision making (Agor 1989).

The appropriate number of people directly involved in strategic planning will depend on the size of the research organization. In small research organizations, the planning team may be very small, consisting of a few key individuals. In medium-size organizations, two groups may be required to help ensure an effective planning effort: a relatively large group to provide broad representation and legitimization of the planning process, and a smaller executive committee that does most of the actual work and makes recommendations to the larger group. Large organizations may want to structure the planning process by establishing several specialized committees. Alig (1989) describes four planning teams set up at the USDA Forest Service, Southeastern Forest Experiment Station:

- Policy team. Consisting of the Station Director and other research managers, the policy team makes decisions and provides input to the planning process.
- Core team. Representatives from management, scientists, information services, and the National Forest System (a major user of research results) make up the core planning team. Their task is to facilitate the planning process by gathering information and making recommendations to the policy team.
- Expert teams. Several teams of senior scientists provide technical expertise, e.g., to ensure that that research goals are in fact attainable.
- Review team. Draft planning documents are reviewed by a team of stakeholders from inside and outside of the Forest Service.

2. Identifying and Clarifying Organizational Mandates

What is the research organization required to do and not do? Consideration should be given to formal mandates such as legal requirements and government policy and appropriations, as well

as to informal mandates such as interest group reports, agreements and understandings with other organizations, and social norms, that are no less binding. The purpose of this step is to identify externally imposed mandates and clarify how they affect the research organization. By clarifying what is not ruled out by the mandates, the rough boundaries in which the organization may operate become clearer.

The process for identifying organizational mandates is straightforward. The strategic planning team (or several individual members) compiles a list of formal and informal mandates affecting the organization. This list is reviewed and modified by the entire planning team to clarify what the various mandates imply for the organization, i.e., What is required? What is allowed? Organizational mandates are one of the important inputs used in developing a mission statement in step 4 below.

3. Conducting a Stakeholder Analysis

Stakeholders are defined as people, groups, or organizations that have a claim on the research organization's attention, resources, or output, or are affected by that output. Examples of stakeholders for a research organization include public officials, governing bodies, a wide variety of interest groups (such as industry groups, conservation groups), extension agents and organizations, future generations, farmers, taxpayers, other public and private research organizations within the country, research organizations in other countries, educational institutions, international donor and technical assistance agencies, and employees. Important employee groups should be explicitly identified as stakeholders. Scientists are perhaps the most important employee group because their own satisfaction is important to the success of a research organization. Moreover, scientists tend to judge organizational performance based on standards of scientific research, and they hold the organization more to exacting scientific and professional standards than other stakeholder groups do.

A key to the success of a research organization and its ability to generate financial and political support is the satisfaction of key stakeholders. An organization that does not have a clear idea of who its stakeholders are, what they want from the organization, and how they judge the organization will have little chance of satisfying them. The stakeholder analysis can be structured around the following questions:

- Who are the organization's stakeholders?
- What do they want from the research organization?
- What criteria do the stakeholders use to evaluate the research organization?
- How is the organization performing against those criteria?

The first question can likely be answered through a brainstorming session of the strategic planning team. The second and third questions can be approached in two ways. One is for the planning team to make informed judgments about the wants and evaluation criteria of stakeholders. The second approach is to ask the stakeholders, through interviews or surveys, what their wants and criteria are. The first approach is obviously much faster and avoids any problems with stakeholders not being completely honest. For example, an elected official may be concerned primarily with whether the performance of the research organization enhances his or her prospects for reelection, but would be unlikely to publicly state this criterion.

The fourth question to be answered in the stakeholder analysis concerns how well the organization performs against the stakeholders' criteria. To prompt useful discussion on this question, it may be sufficient to indicate whether the organization's performance is poor, sufficient, or excellent relative to the various criteria. Once the stakeholder analysis has been

completed, it should serve as a basis for discussion of exactly how the various stakeholders influence the organization and which are the most important stakeholders. It may be useful to rank the stakeholders according to their importance to the organization.

4. Developing a Mission Statement

A well-conceived mission statement can be a valuable management tool, providing future direction and a basis for decision making. A mission statement should ideally serve as a guide to what management wants the organization to be (Pfeiffer et al. 1989). It should remind and motivate researchers and other employees to identify with the goals and philosophy of the organization, and orient employees toward the national needs that the organization exists to fill. Mission statements should also fulfill an important public relations role by concisely communicating to stakeholders what an organization is all about. Unfortunately, many forestry research organizations do not have mission statements — they are noticeably absent from annual reports and other key documents.

The stakeholder analysis provides information that is useful in developing a mission statement, but much more is needed. The mission statement should grow out of responses to the following questions:

- Who are we as an organization?
- What social needs do we exist to fill?
- What should our organization do to recognize or anticipate and respond to these needs?
- How should we respond to our key stakeholders?
- What is our philosophy and what are our core values?
- What makes our organization distinctive or unique?

Thoughtfully addressing these questions and developing a mission statement is a demanding process. Each member of the strategic planning team should answer the questions individually first, and then come together as a group for discussion. After the group discussion, the task of developing a draft mission statement for further discussion should be assigned to an individual. The draft mission statement should be discussed and modified as needed throughout the remainder of the strategic planning process. Figure 2 is an example of a forestry research mission statement for the Newfoundland Forestry Centre of Forestry Canada. It concisely describes what this organization does, who its stakeholders or clients are, and the desired impact of its program.

The Newfoundland Forestry Centre of Forestry Canada is the lead federal agency in Newfoundland and Labrador responsible for:

- conducting forestry research to produce scientific and technical knowledge,
- managing forestry development agreements and related programs,
- disseminating scientific and technical information, and
- providing forest policy advisory services,

to enhance the economic, environmental and social benefits from the forest resources in the region. The principal clients are the provincial, federal, and private forestry related agencies, the scientific community, educational institutions, and the general public. The programs of the NeFC are designed to have a significant impact on the forest sector, primarily in the region, and contribute to national and international knowledge in forestry.

Figure 2. Mission statement for the Newfoundland Forestry Centre, Forestry Canada. Source: Milne (1989).

5. Assessing the External and Internal Environments

A major purpose of strategic planning is to identify external threats and opportunities that may demand a response in the foreseeable future. The idea is to prepare an organization to respond effectively before a crisis develops or an opportunity is lost. Assessing trends in the external environment for research is therefore an important part of strategic research planning. What are the recent issues and emerging trends affecting the research organization? These could include political, economic, social, technological, and environmental trends and issues that may be local, national, or worldwide in scope.

Some large public organizations use formal, institutionalized “external scanning” procedures (Pflaum and Delmont 1987). But elaborate and demanding procedures are generally less desirable than simple and practical approaches. Most research organizations rely on the knowledge of members of the strategic planning team and use group discussions to identify external threats and opportunities and assess their significance to the organization. Other approaches include organizing workshops involving stakeholder representatives to identify major issues, or using various survey techniques (e.g., Milne 1988, Gregersen et al. 1989, Jakes et al. 1990).

The internal environment should also be assessed to identify strengths and weaknesses that help or hinder the organization in carrying out its mission. Broad categories of internal strengths and weaknesses include:

- resources available to the organization (such as scientific and technical personnel, support personnel, scientific equipment, facilities, supplies, library and information resources, computer resources, and funding);
- organizational structure (the institutional forms and mechanisms that govern a research organization and by which research priorities are set and resources are mobilized for the implementation of the research program); and
- organizational performance (outputs and the impacts of outputs on clients).

Using these categories, the planning team should develop a list of the major internal strengths and weaknesses of the organization. This list, along with the list of external opportunities and threats, should then be discussed and analyzed. Pfeiffer et al. (1989) note that scanning and assessing the external and internal environments should be a continual activity in an organization so that relevant information is always available to key decision makers.

6. Identifying Strategic Issues

The preceding steps of the strategic planning process lead to the identification of strategic issues. Bryson (1988) defines a strategic issue as a fundamental policy choice facing an organization. For research organizations, strategic issues affect or call for a reexamination of the organization’s mandates, missions and values, and the kinds, level, and mix of research services provided. Strategic issues usually arise when:

- external events beyond the control of the organization make or will make it difficult to accomplish objectives given the resources available;
- choices for achieving organizational objectives change, or are expected to change (e.g., changes in technology, financing, staffing, management); or
- new opportunities arise (Bryson et al. 1985).

In identifying strategic issues, particular attention is given to potential discontinuities that

might have a major impact on the organization (Hanna 1985). Examples of strategic issues that a research organization might face include an increasing rate of deforestation, increasing conflicts among groups that utilize forests (Jakes et al. 1990), long-term decline in real research budgets or civil service salaries (Bengston 1989), increasing demand for non-timber forest outputs in the future (Sesco and Bey 1989), a high proportion of scientists approaching retirement age (Sesco and Bey 1989), and privatization of research or other significant organizational changes (Theron 1989). Note that some of these strategic issues relate to changing research needs and priorities, and others relate to research policy, organization, and management.

The process of identifying strategic issues involves first reviewing the mandates, mission, external threats and opportunities, and internal strengths and weaknesses. Each member of the planning team is then asked to individually identify strategic issues by answering three questions for each issue:

- What is the issue? The issue should be described succinctly in a single paragraph and should be framed as a question that the organization can address.
- What factors make the issue a fundamental policy question? How does the issue affect mandates, mission, internal strengths and weaknesses, etc.?
- What are the consequences of not addressing the issue? If there are no consequences, it is not a strategic issue; if the organization will be significantly affected by failure to address an issue or will miss an important opportunity, the issue is highly strategic and should receive high priority.

Planning team members will need time to reflect on these questions, and at least a week should be devoted to individual identification of strategic issues. The entire planning team then convenes and tentatively agrees on what the issues are. Each issue should be summarized on a single page, addressing each of the three questions posed above. Strategic issues are then prioritized to aid in developing strategies to deal with the issues.

7. Formulating Strategies to Manage Strategic Issues

Bryson (1988) recommends a five-part process for developing strategies to manage strategic issues. For each issue that has been identified, the following questions should be addressed:

- What are the practical alternatives the organization might pursue to address a particular strategic issue?
- What are the barriers to realization of these alternatives?
- What major proposals might be pursued to achieve the alternatives directly or to overcome the barriers?
- What actions must be taken within the next year to implement the proposals?
- What specific steps must be taken within the next six months to implement the major proposals, and who is responsible?

The purpose of these questions is to clarify what has to be done and who has to do what to deal with each strategic issue. For example, suppose a strategic issue facing a research organization (posed as a question that the organization can address) is: *How can we best recruit and retain a highly talented and qualified research staff?* Practical alternatives to address this particular issue might include:

- Better anticipate shortages of trained research personnel.
- Simplify hiring practices.
- Develop and maintain close ties with universities to identify potential researchers for

recruitment.

- Improve the system of rewards and incentives for researchers to increase retainment.

Using the last alternative as an example, potential barriers to realizing this alternative might include:

- Lack of funding to increase researcher salaries.
- Rigidity of the mandated civil service system limiting possibilities for career advancement in research.
- Lack of funding to establish a program of financial awards for outstanding researchers.

Proposals to achieve the alternative directly (improve the system of rewards and incentives for researchers) or to overcome the barriers might include:

- Establish a program of nonfinancial awards and recognition to reward outstanding research productivity and quality, contributions to technology transfer, etc.
- Provide opportunities for international travel (to attend scientific conferences or training courses) as a reward for productive researchers.
- Provide other nonsalary benefits to productive researchers.

The last two questions of the five-part process involve identifying the specific actions that need to be undertaken and assigning responsibility for carrying out the strategy to an individual or ad hoc committee. Alternatively, the planning team may address only the first question — identifying practical alternatives to deal with a strategic issue — and a key staff member would then be assigned to follow up on one or more of the alternatives as part of the implementation of the strategic plan.

8. Implementing and Monitoring the Strategic Plan

The true test for any strategic planning process is the extent to which it affects the activities of the organization and the behavior of employees. The purpose of strategic planning is to develop a better road map to guide the organization. Unless this road map actually guides decisions and actions, the planning process is nothing more than an academic exercise (Pfeiffer et al. 1989). But implementation of the strategies developed does not follow automatically. Change will be threatening to some and almost inevitably faces resistance. Resistance to the implementation of strategies may take the form of procrastination, “paralysis by analysis,” lack of implementation followup, or even outright opposition.

The role of the director of the research organization in implementing the strategic plan cannot be overemphasized. The director should be closely involved in the process from the outset and must be totally committed to the strategic plan and lead the support. All managers need to be committed to the plan and use it to guide decision making, particularly in developing annual objectives and budgets. Management must communicate the plan and its rationale to all employees, especially those that may be affected by it.

Periodic review and updating of the strategic plan and monitoring of its implementation are vital. Every six months the specific steps to implement the plan should be reviewed. Every year or two the strategies to deal with strategic issues should be reviewed and progress evaluated. And every three to five years the entire strategic plan should be reviewed by the strategic planning team and modified as needed. Barry (1986) notes that many organizations review and update their strategic plans yearly, before planning and budgeting for the coming year.

The Written Strategic Plan

The final written strategic plan should be a summary of the planning team's efforts, usually limited to 10 to 15 pages. The simplest form for a written strategic plan consists of the final versions of some of the components completed by the planning team, such as:

- Mission statement
- Organizational mandates (formal and informal)
- External opportunities and threats (factors that might affect the direction of future programs)
- Internal strengths and weaknesses
- Strategic issues facing the organization
- Strategies to manage the issues
- Plans for implementation

A key staff person should be assigned the task of preparing the first draft of the written strategic plan. The draft is then reviewed and modified by other members of the planning team, by key decision makers, and possibly by external stakeholders. After a final review by internal and external reviewers, the plan will be ready for formal adoption and implementation.

Limitations of Strategic Research Planning

Strategic planning can be a powerful and practical tool for managing research, but its limitations and potential pitfalls should be clearly recognized. Barry (1986) and Rocheteau (1989) discuss the following limitations:

Costs can outweigh benefits. Depending on the scope of the planning effort, strategic planning may be costly in terms of money and human resources, especially the scarce time and efforts of high level research managers. The potential benefits of strategic planning should be weighed against these costs. If the planning effort is likely to fail or to fall significantly short of expectations, resources devoted to planning would be used more productively for other purposes. The question "Will the benefits of strategic planning outweigh the costs?" must be asked at the outset.

Formal strategic planning may be unnecessary. Some research organizations operate effectively by responding quickly to new opportunities and threats as they emerge, or "muddle along" without formal planning. A formal strategic plan may be unnecessary for small research organizations that operate effectively in this manner. In addition, some organizations have gifted leaders that instinctively think and manage strategically. Although such leadership is rare, organizations with unusually insightful and gifted leaders may not need to develop a formal strategic plan.

Planning may become a bureaucratic exercise. One of the main goals of strategic planning is to stimulate forward thinking and creativity. But formal planning efforts sometimes become bureaucratic exercises that actually dampen initiative, creativity, and risk-taking. Some planners may focus excessively on the planning process and neglect strategic thinking.

Planning may be overemphasized. The planning function is only one of the responsibilities of managers. Too much emphasis on planning may result in the neglect of other vital areas of research management. Development of a strategic plan should obviously be put aside when an organizational crisis develops, such as a severe cash shortage.

Concluding Comment

Strategic planning is clearly not a panacea for public research organizations, but it can provide an improved road map to help managers guide their organizations through the uncertain, complex, and changing environment that all organizations must traverse. Although successful research managers have always thought and acted strategically, not all have been particularly successful. Formal strategic planning offers some hope of increasing research managers' chance of success and improving the performance of public forestry research organizations.

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THE USE OF DIFFUSION-ADOPTION THEORY IN EVALUATING FORESTRY RESEARCH

by

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Introduction

Evaluating the benefits and costs of forestry research has recently become an increasingly important topic for forest social scientists and policy makers. Despite the extensive evaluation literature on agricultural research (c.f., Bengston 1985, Ruttan 1982, Norton and Davis 1981), interest in the impacts of forestry research is much more recent.

Evaluating public forestry research was initially encouraged by the Forest and Rangeland Renewable Resources Planning Act of 1974. This legislation requires the U.S.D.A. Forest Service to periodically evaluate the status of renewable natural resources and to propose programs, including research, that satisfy the requirements for properly managing these resources. In 1979, agency research administrators developed criteria for evaluating current and proposed Forest Service research programs. The agency formally recognized the value of research evaluation by establishing the research evaluation work unit at the North Central Forest Experiment Station in St. Paul, Minnesota.

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Numerous evaluations have been conducted since the work unit was established (c.f. Seldon and Newman 1987, Haygreen et al. 1986, Bengston 1984). Bengston (1985) states that most studies have used simple assumptions concerning the diffusion of innovations and that the results may be highly sensitive to these assumptions. The use of untested diffusion assumptions is due to the lack of research findings relevant to forestry's unique characteristics.

Before models which forecast the rate of adoption can be developed, however, initial research on those factors affecting the adoption of forestry innovations must be conducted. Several disciplines have established traditions for conducting diffusion research including economics, geography, psychology, and rural sociology. The analyses conducted on forest landowners largely have followed the rural sociology tradition - focusing on the characteristics of potential adopters as explanatory variables. Sociologists have defined the adoption process as "(1) acceptance, (2) over time, (3) of some specific item – an idea or practice, (4) by individuals, groups, or other adopting units, linked (5) to specific channels of communication, (6) to a social structure, and (7) to a given system of values, or culture," (Katz et al. 1963). While very general, this definition provides the key elements of adoption typically examined in natural resource-related research. Specifically, these are the characteristics of the adopting unit, channels of communication, and the social structure.

Several researchers have identified personal characteristics influencing landowners and foresters to adopt forestry innovations. As with the agricultural literature, the forest landowners studies have revealed that higher education and income levels, contact with professional resource managers, the use of a number of information sources, and an interest in timber management are positively related to the likelihood of adopting forest management practices (Palmer et al. 1985, Sollie 1965). Unfortunately, these findings are of limited value in research evaluations and diffusion studies because they do not involve factors which are policy malleable (Miller 1986, Bengston 1985).

Innovation Decision Process

Rogers (1983) provides a detailed discussion of the adoption decision. He contends that potential adopters progress through a five-step thought process which he terms the innovation decision process. These five steps are termed the Knowledge, Persuasion, Decision, Implementation, and Confirmation.

The initial step, the Knowledge State, begins when the individual is exposed to the new technology's existence and gains some knowledge of the innovation's function. An innovation normally contains three types of information: software knowledge reduces the uncertainty about the "cause-effect relationships" required for successful implementation, how-to knowledge is the information of "how-to" use the innovation properly, and principles knowledge concerns the theory behind the innovation. For example, an understanding of tree physiology and chemistry represent the principles knowledge necessary to comprehend the function of chemical site preparation. Obviously few foresters have the resources to sufficiently educate landowners in principles knowledge. As Rogers notes, the majority of change agents concentrate on creating awareness of the innovation, though their most important role may be in providing how-to knowledge. During this stage, mass media may be the most effective means of creating awareness but are not as useful for providing detailed how-to information. Assistance foresters typically combine the two. While extension foresters concentrate on awareness, the assistance foresters increase landowners' awareness of their management problems and most often offer solutions. Rather than directly transferring the how-to knowledge to the landowner, most private foresters assume the responsibility for applying their recommendations--if the landowner allows. In contrast, most state service foresters attempt to inform their clients to the extent that they can carry out many of the management practices. Little effort is expended to provide principles knowledge as most often a forester's resources are too limited. In their role as adopters of new innovations, foresters are in

a much more advantageous position to evaluate new technology. Their college education has provided them with the principles knowledge concerning forest management. The remaining tasks in this state, therefore, involve becoming aware of the innovations and how they operate.

During the persuasion stage, the decision-maker develops an attitude towards the innovation. At this point, the decision-maker seeks additional information which is then used to form a favorable or unfavorable attitude. Important determinants of subsequent adoption during this stage include where the decision-maker seeks information, what information is received, and how this information is perceived. The importance of selective perception is critical. Rogers suggests that the attributes most often considered at this stage are the relative advantage, compatibility, and complexity of the innovation. For most landowners, and not surprisingly for the U.S. Forest Service and Cooperative Extension Service, comparative advantage often is interpreted as economic advantage as the costs and benefits of changing current management regimes are weighed.

In addition to supplying information on costs and returns, foresters can also provide landowners with ideas on the compatibility of the innovation with current management practices and some estimate of the complexity of applying the innovation. However, the forester's effectiveness at influencing the probability of a favorable attitude is somewhat limited during this stage. As established elsewhere (Rogers 1983), the decision-makers (landowners) primarily rely on peers for the above information, reflecting the general preference for personal experience over scientific or professional information.

During the third stage of Rogers' innovation-decision process, the decision-maker determines whether to adopt or reject the innovation. Indeed individuals often try the innovation on a limited basis before deciding whether to adopt the innovation completely. Unfortunately, given the time frame and characteristics of most forest management practices, such trials may not be feasible. Landowners, therefore, rely on past clients of the assistance foresters or forestry demonstrations.

Crossett Experimental and Demonstration forest in southeast Arkansas is perhaps the most popular example of a forest managed to demonstrate the benefits of forest management practices and innovations to landowners. As with the persuasion stage, personal contacts remain the major source of information, although foresters, through demonstrations of the innovation's successful adoption can have considerable impact.

The implementation stage involves the actual use of the innovation. The adopter, continues to seek information, both on its successful use and for remedies for problems which might arise. The forester's role as change agent is crucial, especially since, the forester carries out the actual implementation. Despite this, the adopter continues to rely on landowners with past experience in an effort to reduce the remaining uncertainty.

The final stage of the innovation-decision process is confirmation or reinforcement of the innovation decision. Rogers notes the decision-maker attempts to either avoid or reduce dissonance, that is, the individual attempts to maintain agreement between attitudes and activities. Foresters assist in this stage by supplying additional information concerning the innovation's benefits derived by previous adopters or quickly resolving any difficulties that arise. In terms of the forester's decision to adopt, dissonance may be avoided or reduced by conferring with colleagues and specialists or altering the innovation to more closely fit the needs of the forester. For both landowners and foresters, if the dissonance is too great, the innovation may be discontinued.

Recent Empirical Studies

While most of the early adoption-diffusion research in forestry focused on the adoption decisions of private forest landowners, recent studies have been concentrated on the behavior of foresters. This research is crucial if we are to successfully evaluate the likelihood of both organizations and private landowners ultimately adopting new and emerging forest management

technology. To date, the results of three forester adoption studies have been published, and have examined the behavior of foresters in the southern U.S., the Lake States, and New Hampshire.

Such research is important to adoption-diffusion research and research evaluation for two reasons. First, foresters represent the primary adopting unit for most public land management agencies and forest products firms. As a result, their behavior directly affects the timing of adoption. Secondly, state service foresters and private consultants, who assist private landowners must face the adoption decision process before encouraging landowner to adopt the technology. Assistance foresters, therefore, act as both adopters in evaluating new technology and as change agents in encouraging landowners to adopt forest management innovations.

Adopting Computer Programs

Miner (1986) examined the adoption decisions of foresters in the Lake States (Michigan, Minnesota, and Wisconsin) regarding computer growth and yield programs. She concentrated on how the adoption decision was affected by computer availability, organizational innovativeness, communication channels, and knowledge obsolescence, or the extent that the availability of the computer software will make the foresters' knowledge obsolete. Foresters who perceive that the software will result in obsolescence were hypothesized to be less likely to adopt the computer programs than those with more positive perceptions.

More than 400 foresters were surveyed via mail questionnaires, with 323 responses, or 74 percent, being used for the analyses. The results indicated that 26 (8 percent) of the respondents had used at least 1 of the 2 programs studied (STEMS and TWIGS). Public foresters, both federal and state, constituted the bulk of adopters. Adoption of the programs and computer availability were highly correlated, as would be expected. Forty-eight percent of non-adopters indicated that computers were available, compared to 85 percent of the adopters. Similarly, 89 percent of the

adopters perceived their employer or organization as innovative. Sixty-two percent of the non-adopters viewed their organizations as innovative, a difference which was significant at the 0.05 level between the two groups.

The influence of communication channels was evaluated with two variables: (1) read about STEMS/TWIGS in journals or other publications, and (2) attended STEMS/TWIGS workshops. Differences between adopters and non-adopters were obtained at the 0.05 level. Almost all adopters (96 percent), and 72 percent of the non-adopters, had read about STEMS/TWIGS in journals, Forest Service publications, or other forms of printed material. Attendance at STEMS/TWIGS workshops, produced similar results, with 54 percent of the adopters and 27 percent of the non-adopters attending the workshops. Miner reported no differences for the knowledge obsolescence variable. Ninety-two percent of both groups reported no concern about the software rendering the forester's knowledge obsolete.

Miner concluded that computer availability, organizational innovativeness, and communication channels affect the adoption decisions regarding STEMS and TWIGS. All of these variables are largely determined by the organizational environment. At the time of the study, computers, publications, and workshops were most accessible to federal foresters. State foresters, though characterized by more limited computer availability, were also like to adopt the programs. Miner attributes this to the formal and informal relations between the federal and state foresters. Finally, private foresters were the least likely to adopt the software, perhaps reflecting the limited availability of computers for industry and consulting foresters.

Adoption Behavior of Southern Foresters

The second study examined the decisions of foresters in 12 southern states with respect to their forest management practices (Hodges and Cubbage 1990). Logit analysis was employed to

determine how a forester's employer, activity level, channels of communication, and perception of his/her management situation affect the adoption decisions. Logit analysis represents one of the more commonly utilized multivariate regression techniques for analyzing a dichotomous dependent variable. Here the dependent variable was whether the forester had or had not changed his/her management practices during the past five years.

Preliminary Results. -- Approximately 300 questionnaires were mailed to state service foresters, consulting foresters, and industry foresters with responsibilities for assisting nonindustrial, private forest landowners. Eighty-two percent of the sample population (240) returned completed surveys. The surveys included questions concerning the forester's employer, the extent and type of assistance provided to private landowners, communication channels used for obtaining information, and perceptions of the specific management situation faced. Of the 240 respondents, 214 completed the section of the survey pertaining to changes in management practices. The remaining 26 had not been practicing forestry for 5 years.

The results revealed several significant differences among the adopters and non-adopters. Of the 214 respondents, 163 foresters indicated that they had changed their forest management practices in the preceding 5 years. The most commonly selected factors for the change in management practices included to reduce costs, increase timber yields, and respond to new information. Interestingly, no significant difference was found between the number of information sources used by the two groups. Foresters who had changed their management practices utilized 4.5 sources of information, while non-adopters averaged 3.7 sources (Hodges 1988).

Non-adopters relied primarily on journals and regional meetings for information. Journals serve as the profession's mass media by providing general information on current problems and new techniques. Regional meetings also serve to present new ideas that are applicable to the specific

problems of the region. While such meetings provide excellent opportunities to converse with colleagues on the relative merits of new developments in forest management, less than one-half of the non-adopters who listed these meetings as a source of new information noted the importance of fellow professionals. In contrast, adopters utilized the mass media, as well as colleagues and training sessions for information.

One characteristic of early adopters is the use of information sources close to the originator of the innovation (Bertrand and South 1963). University faculty and publications were listed as information sources by 32 percent of the adopters and only 18 percent of the non-adopters. The use of U.S. Forest Service publications was approximately equal for both groups.

Logit analysis. -- Based on the results of the preliminary analysis, several variables were selected for evaluation within the logit framework. These included a variable representing the respondent's employer, measures of landowner assistance activity, dummy variables for the use of communication networks, and variables for the respondent's perception of the management situation that they typically encounter (Table 1).

The forester's perceived management situation consisted of responses to a battery of 20 statements each of which indicated how closely the statement represented their particular situation (1 = not representative, 5 = very representative). These responses were then factor analyzed in order to consolidate them. Factor analysis is a multivariate statistical method designed to describe the covariance structure among a large set of variables in terms of a reduced number of underlying dimensions. This data reduction technique produced 5 factors which represented the applicability of even-aged management, multiple use objectives, economic concerns, landowner knowledge, and natural stand management. This information, in factor score form, was included in the logit analysis.

The results of the logit analysis are presented in Tables 2. Eight variables were included in the final model, with all variable types being represented by at least one variable. Partial derivatives were calculated for each variable and represent the probability of change corresponding to a one-unit change in an independent variable evaluated at the means.

The respondent's employer (EMPLOY) was positively and significantly related to the probability of a change in forest management practices. State service foresters was the employee type most likely to change management practices, followed by industry foresters, while consultants were the least likely to change management practices. OWNERS, or the number of landowners assisted, was positively related to the propensity to change management practices as well. Here, a one-unit increase in the number of landowners assisted would correspond to a 0.1 percent increase in the probability of changing practices.

Several communication network variables were significantly related to the change decision. Using foresters outside the organization (FOUT) and university sources (UNPUB) increased the likelihood of change by 9.3 and 8.8 percent, respectively. Conversely, membership in the Society of American Foresters (SAF) decreased the probability of change by 11 percent. This perhaps reflects that SAF members rely almost exclusively on the Society's publications as sources of information, while adopting foresters rely on a more extensive information network. The finding may also suggest that SAF needs to enhance its technology transfer efforts.

Finally, the factors concerning the applicability of even-aged management and the riskiness of natural stand management were significantly related to the change of management practices. Foresters facing situations where managing for even-aged stands was typical or where natural stand management was risky would be more likely to change their management practices. The results indicate, therefore, that foresters who rely primarily on even-aged management techniques are more likely to adopt innovations than those who practice less intensive forms of management. It is not

evident, however, whether this result is caused by forester characteristics or the past forest management research emphasis. Few foresters would argue that the greatest research emphasis during the past 30 years has been placed on intensive, even-aged management. A determining factor in the increased probability of change for foresters practicing even-aged management then may be that most innovations in forestry in recent years have been in this management type.

Use of Soils Information in New Hampshire

The last adoption study examined the use of forest soils information by foresters in New Hampshire (Parmele 1989). Three types of soils information were evaluated: County Soil Survey information regarding woodland productivity potential and forest management limitations, Important Forest Soils Groups (Spielman et al. 1984) which was developed to provide easily applied information on soil-silvicultural relationships, and the Habitat Classification System developed by Leak (1982) which represents a bio-physical classification system.

Questionnaires were mailed to 437 New Hampshire foresters, including federal and state foresters, industry foresters, and private consultants. Thirty-seven names were eliminated from the list for various reasons, leaving a final sample population of 400. Of the 400, 238 foresters returned completed questionnaires for a response rate of approximately 60 percent.

Preliminary results. -- The use of the forest soils information varied considerably over the three sources. More than 70 percent of the foresters indicated that they had used the County Soil Surveys for forest management activities, with 41 percent noting that they had used the information at least 4 times during the past year. Less than one-half as many foresters (30 percent) had utilized the Important Forest Soils Groups information, with 9 percent using it 4 or more times during the year.

Leak's Habitat Classification System was utilized by only 13 percent of the respondents, with 7 percent employing the system 4 or more times during the year.

Much of the variation in use of these sources can be traced to the length of time that each has been accessible. Both the Important Forest Soils Groups and Habitat Classification System were published after 1980, while County Soil Survey information has been available for several decades. As a result, foresters have had more time to learn about the Soil Surveys. The foresters' sources of information provide additional insight into this differentiation. Since the mean year of college graduation for the respondents was 1970, only a small portion of the respondents would have been exposed to the two new forest soils classification systems in the classroom.

Discriminant analysis. -- In order to determine the significant factors in the adoption decision of foresters, the discriminant analytical technique was employed. This procedure determines the differences between two or more groups, with respect to a set of independent variables. A linear combination of the independent variables called the discriminant function is formed, allowing for assignment of individuals into maximally separated groups. The coefficients are determined so that each group's value on the discriminant function, called the group centroid, differs as much as possible from the discriminant function values of the other groups.

In each of the three analyses, the dependent variable was dichotomized on the decision to utilize each particular forest soils information. The independent variables included age, employer, attitudes towards the importance of soils information to forest management, and sources of information. Employer and information sources were the most important variables in the three discriminant analyses (Table 3). The three employer variables revealed that industry and self-employed foresters would be more likely to adopt the Soil Survey information, while foresters employed by the U.S. Forest Service would be very unlikely to do so. Non-college sources of

information had the highest standardized coefficient in the Soil Survey analysis, followed by the age and employer variables. The model explained 28 percent of the variance.

The Important Forest Soils Groups discriminant analysis provided similar results. The model was dominated by two sources of information variables, College and Non-college. Other important variables included "Prior use of county soil information" and "Importance of forest soils information". The model correctly classified 86 percent of the foresters, with a significant improvement over the Soil Survey model in classifying non-adopters. This model explained 43 percent of the variance in adoption.

The discriminant analysis for Leak's Habitat Classification System provided the best classification model, correctly identifying 92 percent of both adopters and non-adopters. As in the previous models, Non-college sources of information was the dominant variable. The model accounted for 53 percent of the variation in adoption.

Discussion

Each of the three studies reviewed the applicability of adoption-diffusion research for evaluating the adoption of forestry technology. All of these analyses reveal the importance of employer and information services on the innovation decision process.

Interestingly, there is little evidence that sociodemographic characteristics affect the adoption decisions of foresters. This is perhaps the result of little variation among foresters in terms of income, education, and background. The bulk of practicing foresters in the United States have earned Bachelor of Science degrees in forestry. Because these schools must meet the curriculum requirements of the Society of American Foresters for accreditation, the undergraduate curricula are very similar. As a result, most foresters share a common educational background. Hodges

(1988) and Parmele (1989) both note that graduate education has no effect on the adoption behavior of their sample populations. Finally, foresters share a set of common beliefs, as do most professions. Kaufman (1960) notes that the indoctrination into the U.S. Forest Service system begins in forestry school. Although a much smaller percentage of the total forester population is employed by the Forest Service today than during Kaufman's study, forestry students and foresters share a common core of beliefs. As a result, there are few sociodemographic or attitudinal variables that should be expected to exhibit wide variation among this segment of the population.

Information sources were the most significant influences in all three studies. Sociologists have recognized the importance of information in the adoption process for some time. In recent years, differential access to information sources has been considered the overriding factor in adoption analysis. Rogers (1983), in a survey of adoption research, notes that adopters are characterized as having more social participation, greater access to communication channels, and are more highly interconnected to the social system. The findings of Hodges and Cubbage (1990) and Parmele (1989) support these conclusions. Significant sources of information for the southern foresters consisted of foresters outside the respondent's organization and university sources. Non-adopters were characterized as relying on forms of mass media for new information. Parmele reported that external sources of information were most important in the discriminant analyses. Adopters clearly can be characterized as relying on a much more extensive communication network than the non-adopters.

Type of employer was also a significant factor in all three studies. For the most part, public foresters (federal and state) were more innovative than privately or self-employed foresters. Two explanations were offered for this difference in behavior. Hodges and Cubbage (1990) attribute it to differences in risk aversion and organizational objectives. State service foresters assume responsibility for increasing landowner awareness. As a result, state foresters experiment with a

wide range of management alternatives to satisfy the objectives of a diverse set of landowners. Self-employed foresters, on the other hand, rely on income generated from their management activities, and are much less likely to deviate from successful management techniques. Industry foresters can assume a more moderate stance, as their organizational success is linked to their management expertise, though not as closely as the self-employed foresters. Parmele (1989) attributes the employer effect to information access. This is particularly relevant to the adoption of forest soils information, where one of the sources (Leak's Habitat Classification System) was developed specifically for the White Mountain National Forest.

Implications for Future Research

These studies provide a sound base for applying a sociological approach to forestry adoption analysis. Indeed, we now have results from three separate analyses, in terms of geographic distribution, analysis techniques, and subject matter. All three reach similar conclusions regarding the influence of employer and information sources on foresters' adoption decisions.

More work is needed, however, before the information gained from these studies can be applied to forestry research evaluations and technology transfer efforts. Most notably, we must examine how the variables identified by the previous work affect the timing of adoption. Rogers (1983) notes that the importance of specific information sources varies throughout the innovation decision process. More information is needed, therefore, on when foresters utilize the various information sources. Additionally, political and economic factors must be incorporated into future adoption studies. As many foresters noted in the southern study, a technology's comparative advantage is an important consideration. The timing of adoption obviously could be estimated more precisely if such factors were considered.

In addition, both Hodges (1988) and Parmele (1989) note the need to improve the definition of the dependent variables used in such analyses. Both studies did not rely on the adoption of "innovations", but rather the use of existing or modified technology. Modeling the diffusion of a forest management innovation from its development through its successful adoption is crucial. Such an analysis would provide valuable insights into the influence of adopter characteristics, economic and political factors, and the nature of the innovation on the diffusion of the technology. Research evaluations can then be developed with reliable information on the timing of adoption.

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Table 1. Independent Variables Tested in Logit Regression Model of Change in Management Practices

<u>Variable Group</u>	<u>Variable</u>	<u>Description</u>	<u>Measurement</u>
Objectives	EMPLOY	Forester's employer	1,2-consultant 3- industry 4-state
Activity	OWNERS	Number assisted	reported number
	TRTAC	Acres treated	acres regenerated + T.S.I. acres
	HARAC	Acres harvested	acres reported for all harvesting methods
Communication	FWOR	Foresters within own organization	1-used as source 0-otherwise
	FOUT	Foresters outside own organization	1-used as source 0-otherwise
	UNPUB	University faculty and publications	1-used as source 0-otherwise
	SAF	Society of American Foresters	1-member 0-otherwise
Management	FACTOR 1	Factor relating to applicability of even-aged pine management	factor score
	FACTOR 2	Factor relating to popularity of non- timber objectives by landowners	factor score
	FACTOR 3	Factor relating to economic factors	factor score
	FACTOR 4	Factor relating to landowner know- ledge of forest management prac- tices and product markets	factor score
	FACTOR 5	Factor relating to difficulty of us- ing natural stand management prac- tices	factor score

Table 2. Final Logistical Regression Model for the Likelihood of Change in Management Practices.

<u>Variable</u>	<u>Mean</u>	<u>Beta</u> <u>(t-ratio)</u>	<u>Derivative</u> <u>(prob @ mean)</u>
Intercept	--	0.0966 (0.10)	
EMPLOY	2.852	0.3915** (1.94)	0.36
OWNERS	140.586	0.0074*** (2.06)	.001
SAF	0.657	-1.1831*** (2.140)	-.110
FOUT	0.420	1.0119*** (2.05)	.094
UNPUB	0.284	0.9522** (1.75)	.088
FACTOR 1	0.004	0.6202*** (2.11)	.057
FACTOR 2	0.025	-0.6867**** (2.71)	-.064
FACTOR 3	0.030	-0.42818 (1.31)	-.040

P(Y-1) @ means .897

**** significant at α - .01

*** significant at α - .05

** significant at α - .10

X^2_3 - 48.36 α < .001

Table 3. Discriminant Analysis Results - Summary/Comparison

Variable	County Soil Survey Information	Important Forest Soils Group	Leak's Habitat Classification System
Age	-0.50		---
Year finished school			+0.02
Length of time in community			-0.13
Importance of forest soils information to foresters	+0.33	+0.19	+0.01
Effect of soil factors on growth			+0.09
Number of conferences attended	+0.16	0.14	+0.05
Percent of time practicing multiple use management		+0.10	+0.11
Non-college sources of information	+0.73	+0.83	+0.93
College sources of information		+0.60	
Forestry employment			
X ₁	0.36		-0.11
X ₂	0.22		-0.02
X ₃	-0.51		+0.05
Prior use of County Soil Survey Information		+0.33	

APPENDIX

PROGRAM FOR THE AUGUST 7-9, 1990, MEETING OF IUFRO SUBJECT GROUP S6.06/S6.08 AT XIX CONGRESS OF THE INTERNATIONAL UNION OF FORESTRY RESEARCH ORGANIZATIONS, MONTREAL, CANADA.

SPEAKERS ATTENDING THE AUGUST 7-9, 1990, MEETING OF IUFRO SUBJECT GROUP S6.06/S6.08 XIX CONGRESS OF THE INTERNATIONAL UNION OF FORESTRY RESEARCH ORGANIZATIONS, MONTREAL, CANADA.



AGENDA

S6.06 - RESEARCH MANAGEMENT FOR THE FUTURE

August 7, 1990

DENVER P. BURNS, LEADER S6.06

SESSION 1 - MODERATOR: DR. STAN BARRAS

TITLE: RESEARCH MANAGEMENT

<u>TIME</u>	<u>SUBJECT</u>	<u>SPEAKER</u>
4:30 - 4:50 p.m.	A New Approach to Managing Multi-Client Forest Research Program	Dr. Colin O'Loughlin Ministry of Forestry Forest Research Institute Wellington, New Zealand
4:50 - 5:05 p.m.	Research and Education Systems for Private Forestland Management and Woodland Utilization	John A. Vance, Deputy Administrator USDA Extension Service Washington, DC
5:05 - 5:20 p.m.	Sugar Maple Decline Project Implementation	Dr. Max McFadden, Program Manager Eastern Hardwoods Research Cooperative USDA, Forest Service Radnor, PA
5:20 - 5:40 p.m.	North American Sugar Maple Decline Project -- Data Acquisition and Preliminary Results	Dr. Doug Allen Professor of Forest Entomology State University of New York Syracuse, NY
5:40 - 6:00 p.m.	Quality Assurance/Quality Control Implementation and Evaluation in the North American Sugar Maple Decline Project	Bill Burkman*, I. Millers, D. Lachance N.S.I. Technical Services Corp. % USDA Forest Service Radnor, PA
6:00 - 6:15 p.m.	Forestry Research - An Interdisciplinary Approach	Dr. Abdul Manap Ahmad, Dean University of Malaysia, Faculty of Forestry Sedang, Selangor, Malaysia
6:15 - 6:30 p.m.	Research's Hidden Assets -- Tapping into Employee Knowledge and Experience	Dr. Denver P. Burns, Director Northeastern Forest Experiment Station Radnor, PA

*Will present paper



AGENDA

S6.06/S6.08 - RESEARCH MANAGEMENT FOR THE FUTURE

August 9, 1990

DENVER P. BURNS, LEADER S6.06

SESSION 2 - MODERATOR: DENVER P. BURNS

TITLE: RESEARCH PLANNING AND EVALUATION

<u>TIME</u>	<u>SUBJECT</u>	<u>SPEAKER</u>
2:00 - 2:20 p.m.	Development Agenda for the 90s	Dr. Jerry SESCO, Deputy Chief Research and Cal Bey, Special Assistant to Deputy Chief Washington, DC
2:20 - 2:40 p.m.	International Forestry Products Program at FPL	John Erickson, Director Forest Products Laboratory Madison, Wisc.
2:40 - 3:00 p.m.	The Productivity of Forest Research: Recent Experience from five U.S. Industries and Their Implications for the Rest of the World	William Hyde, Chief, Dave Newman, and Barry Seldon Economic Research Service; Soil & Water Branch Washington, DC 20005 -- 4788
3:00 - 3:30 p.m.	(1) Strategic Research Planning (2) The Impacts of Technical Change on Outdoor Recreation: A Technical Assessment Framework	Dr. David Bengston, Author Given by Dennis Bradley Research Forester USDA Forest Service North Central Forest Exp. Station St. Paul, Minn.
3:30 - 4:00 p.m.	The Use of Diffusion-Adoption Theory in Evaluating Forestry Research	Donald G. Hodges, Assistant Professor, University of Natural Resource Management University of New Hampshire Durham, N.H.

**PRESENTERS AT THE AUGUST 7-9, 1990, MEETING OF IUFRO
SUBJECT GROUP S6.06/S6.08 AT MONTREAL, CANADA**

Dr. Colin O'Loughlin, Ministry of Forestry, Forest Research Institute, Wellington, New Zealand

Mr. John A. Vance, Deputy Administrator, USDA Extension Service, Washington, D.C.

Dr. Max McFadden, Program Manager, USDA Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Dr. Doug Allen, Professor of Forest Entomology, State University of New York, Syracuse, NY.

Dr. William Burkman, Forest Health Monitoring Coordinator, USDA, Forest Service, Northeastern Area - State & Private Forestry, Radnor, PA.

Dr. Abdul Manap Ahmad, Dean, University of Malaysia, Faculty of Forestry, Sedang, Selango, Malaysia.

Dr. Denver P. Burns, Director, USDA, Northeastern Forest Experiment Station, Radnor, PA.

Dr. Jerry SESCO, Deputy Chief for Research, USDA, Forest Service, Washington, D.C.

Dr. Cal Bey, Special Assistant to Deputy Chief for Research, USDA, Forest Service, Washington, D.C.

Dr. John Erickson, Director, USDA, Forest Service, Forest Products Laboratory, Madison, Wisconsin.

Dr. William Hyde, Chief, USDA, Economic Research Service, Soil & Water Branch, Washington, D.C.

Dr. Dave Newman, USDA, Economic Research Service, Soil & Water Branch, Washington, D.C.

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Dr. Dennis Bradley, USDA, Forest Service, North Central Forest Experiment Station, St. Paul, Minn.

Dr. Donald G. Hodges, Assistant Professor, University of Natural Resource Management, University of New Hampshire, Durham, N.H.

Burns, Denver P., tech. coord. 1991. **Research management for the future**; 1990 August 5-11; Montreal, PQ. Gen. Tech. Rep. NE-157. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 143 p. <https://doi.org/10.2737/NE-GTR-157>

Presents technical papers delivered at the 19th World Congress of the International Union of Forestry Research Organizations held in Montreal, Quebec, Canada, on August 5-11, 1990.

Keywords: Sugar maple, research planning, research evaluation, forest products

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Parsons, West Virginia

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University Park, Pennsylvania, in cooperation with The Pennsylvania State University

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