CFRU Information Report 34

1993 ANNUAL REPORT AND

RESEARCH SUMMARY OF THE

COOPERATIVE FORESTRY RESEARCH UNIT

COLLEGE OF NATURAL RESOURCES, FORESTRY AND AGRICULTURE

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION

UNIVERSITY OF MAINE

ORONO, MAINE 04469

Miscellaneous Report 383

December, 1993

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This CFRU Annual Report and Research Summary provides information from research studies recently completed or in progress. To provide our cooperators with the most recent information available, some of the data and data analyses are preliminary, and should not be quoted without author permission.

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ADVISORY COMMITTEE CHAIR'S REPORT

The Cooperative Forestry Research Unit has successfully completed its 17th year of operation. The eight scientists responsible for the three program and five cooperating project areas made an especially impressive effort at technology transfer activities this year. They provided or participated in over 50 events where information generated by the CFRU has been disseminated. These activities underline the benefits of CFRU to industry cooperators, state agencies, and the general public in providing information needed to make responsible resource management decisions.

Support for the CFRU has remained solid through the recent recessionary years, and is expected to grow stronger as the economy continues to improve. The conservative financial management of the CFRU has again allowed contributions to be calculated on the $0.05 per acre formula for the third consecutive year. This will again provide substantial relief to cooperators, most of whom have had to deal with difficult economic decisions.

Scheduling of the CFRU Advisory Committee meetings was changed this year. The summer field meeting and the fall meeting were combined into a two and one-half day work session. This allowed for a one-day retreat of CFRU program scientists and CFRU Executive Committee members, a one-half day CFRU Advisory Committee business meeting, and a one-day field tour. This schedule allowed time for a more focused technology transfer exchange to occur during the field tour.

At the retreat, a review was made of progress on the revised problem analyses of the program scientists. These documents will be in final draft form for Advisory Committee review by January of 1994. These analyses will form the structure within which research work will be completed over the next three years, and provide an outline of directions for research for the next five-year (1996-2001) research period.

The field tour, conducted by Dr. Max McCormack, highlighted long-term studies on intensive management of spruce and fir at the Austin Pond Study site. Prior to the field tour, Dr. McCormack provided a general overview of the studies. As part of the field tour, Dr. Briggs and Dr. Servello also provided current research information and led excellent discussions related to spruce-fir management. The field tour was well attended, and extremely well executed, despite uncooperative weather. The recommendation is to continue this format of combined meetings, allowing for a full-day field tour, in future years.

I extend my appreciation to all the CFRU scientists and staff, to the other members of the CFRU Executive Committee, and to the cooperators, for making this another profitable research year. The continued success of this endeavor will ensure continued improvement in the management of our forest resources.

Everett Deschenes, Chair
CFRU Advisory Committee

Dr. M. McCormack describes some of the results from the Austin Pond study to cooperators during the September field tour.

DEAN'S REPORT

The Cooperative Forestry Research Unit has completed another successful research year as this annual report illustrates. A wide array of topics is being addressed, from traditional silviculture and timber growth and yield activities to utilization of mill residuals and wildlife issues. The ability of the CFRU to address such a breadth of topics fits exceptionally well into the expanded and interdisciplinary focus which the college has now undertaken in its new structure.

The College of Natural Resources, Forestry and Agriculture was established on July 1, 1993, by combining the former College of Forest Resources and the College of Applied Sciences and Agriculture. The transition to a new college has taken the support, dedication, and hard work of all the faculty, staff, and students. I thank each of them for moving the process forward and for their patience during the conversion process. Although we are continuing to make minor adjustments to this new arrangement, the new college has been well received. Student enrollments remain strong, and the academic quality of incoming students has improved.

The CFRU Executive Committee has had an active year in providing guidance and encouragement in enhancing the technology transfer and communications efforts of the CFRU scientists. Their work has also led to the reestablishment of the membership committee. The membership committee will become increasingly important as major land ownership changes are addressed, and as we prepare to enter the fifth five-year research period in 1996.

I especially welcome Mr. Rick Dionne to the CFRU as the new Research Associate in the Silviculture Program. I know that Rick has eagerly accepted his new responsibilities and will be a tremendous asset to the CFRU. I also take this opportunity to welcome back Bob Shepard from his extended hospital stay and wish him all the best in his return to work.

It has been a pleasure to interact with all the cooperators through this past year. Your continued enthusiasm and support for the CFRU, and for the college as a whole, is most gratifying. I look forward to working with all of you in the coming years, as we continue to address the natural resource issues so critical to our society.

G. Bruce Wiersma, Dean
College of Natural Resources, Forestry
and Agriculture

Dr. R. Briggs demonstrates the application of a site classification field guide for spruce and fir at the Austin Pond study site.

BALANCE SHEET

1992-1993
Period 10/1/92-9/30/93

ASSETS:

BALANCE FORWARDED SEPTEMBER 30, 1992	$ 709,187.17	
FUNDS RETURNED TO CONTROL AFTER adjustments on 09/30/92	6,490.33	
INVESTMENTS 10/01/92-09/30/93	23,074.65	
CONTRIBUTIONS 01/01/92-09/30/92	407,872.00	
TOTAL ASSETS:		$1,146,624.15

EXPENSES: 10/01/92-9/30/93

VEHICLE REPLACEMENT	15,000.00	
ADMINISTRATION - OSTROFSKY	56,270.85	
MOOSE & HERBICIDES - SERVELLO	34,023.80	
SILVICULTURE - McCORMACK SOIL	113,038.45	
SITE -- BRIGGS HARDWOOD/ASH -	129,007.00	
OSTROFSKY GROWTH/YIELD -	86,656.00	
SEYMOUR TREE IMPROVEMENT --	13,166.77	
GREENWOOD SLUDGE & ASH -	8,513.42	
SHEPARD TREE IMPROVEMENT -	10,539.61	
CARTER	19,901.27	
TOTAL EXPENSES: BALANCE		486,117.17
09/30/93 LESS DEDICATED		660,506.98
FUNDS: BALANCE ENDING		400,000.00
09/30/93		260,506.98

CFRU LEADER'S REPORT

The CFRU research effort continued to make significant progress through 1993. Substantial summaries of research on stand dynamics of spruce and fir at the Austin Pond study site, and of a spruce-fir site classification guide were developed or are near completion. The wildlife project examining herbicide effects on habitat for moose and deer was also completed.

Many other projects continued to generate valuable information. A significant data base is now accumulating on effects of forest land spreading of residual papermill sludge and ash materials. Focused work in the Tree Improvement and the Growth and Yield projects also continue to provide significant, practical data.

Rick Dionne was hired as the new Research Associate for the Silviculture Program and is working under the direction of Dr. M. McCormack. Rick started work in April and has brought with him a high degree of enthusiasm and energy to his position. We welcome him as an important part of the CFRU research program.

Over the past year, there have been some significant land ownership changes. This has prompted the CFRU Executive Committee to reestablish a Membership Committee for the purpose of encouraging new landowners and others to become supporting members. The committee will begin its work during the coming winter and will help to set the groundwork for developing the next five-year (1996-2001) research period.

During the CFRU retreat in 1992, it was agreed that more emphasis be placed on promoting technology transfer and communications efforts. One outcome has been to develop a monthly communication on CFRU research for use in cooperator newsletters, or other outlets as appropriate. This supplements the considerable effort already made to technology transfer activities, as can been seen from the list in this annual report.

A successful summer field tour was conducted at the Austin Pond study site, with over 80 people attending. The tour, organized and conducted by Dr. M. McCormack, was well received as a new format for providing a more formal technology transfer opportunity for cooperator personnel. The success of the tour was also due, in large part, to a substantial effort by Lynne McCormack, the CFRU staff and associated graduate and undergraduate forestry students, and to Scott Paper Company.

On a personal note, Dr. R. Shepard became seriously ill during late 1992 and was hospitalized for over five months. Since his release from the hospital in late spring, his health has improved greatly. Despite this extensive loss in time, Dr. Shepard has obtained most of the critical field data for this past growing season. We are pleased that he has made a rapid recovery and wish him continued good health.

The projects described in this report, along with many other previous and on-going studies, have positioned the CFRU in the forefront of providing improved understanding and management of the forest resources. The CFRU remains vital and ambitious and looks forward to the research challenges that the new year will bring.

William D. Ostrofsky, Leader
Cooperative Forestry Research Unit

Dr. F. Servello reports on his studies of moose and deer habitat during the September field tour at the Austin Pond study site.

SILVICULTURE

Dr. Maxwell L. McCormack, Jr.

OVERVIEW

Early in the year a successful search concluded with the employment of Rick Dionne of Bradley, Maine, as the full-time Research Associate with the Silviculture Program. Rick holds a BS degree in forest management from the University of Maine and brings many years of construction contracting and military experience to the project. This is the first year of my 25 percent reduced time within the university's phased early retirement program. This reduction makes it possible to bring other aspects of the Silviculture Program back to a full scale effort. In addition, in March, I was appointed Henry W. Saunders Professor of Hardwood Silviculture. This adds a timely, new dimension to our silviculture research program.

During June a part-time effort was devoted to a two-week silviculture tour in Germany and Switzerland. Several participants from CFRU cooperators took part in field excursions with hosts showing a variety of forestry activities. There was an emphasis on thinnings, crop tree selection and spacings, and uneven-aged silviculture. Major impressions centered around the long-time period of detailed forestry records, intensive focus on crop trees intended to grow to large sizes, and a devotion to maintaining healthy forests. Thanks to an old scrapbook provided by Bob Frank of the Northeastern Forest Experiment Station, we were able to retrace part of a tour of the same region made by Austin Gary in the 1890s (Figure 1).

It is interesting to note the development of projects within the Vegetation Management Alternatives Program (VMAP) of the Ontario Ministry of Natural Resources in Sault Ste. Marie. A strong component is the contribution of R. A. Lautenschlager, formerly the Assistant Scientist and a graduate student in our Silviculture Program, as he expands on many of the project efforts with which he worked while he was with CFRU. The VMAP is one of the largest vegetation management research efforts in North America and, because of its location, is developing information with application to our region".

Technology transfer activities included participation in the 14th Annual California Vegetation Management Conference, a briefing on herbicide uses in forestry for congressional members and staff in Washington, D.C., hosted by RISE (Responsible Industry for a Sound Environment), the Ontario Advanced Forestry Program at Lakehead University, and a radio talk program on WERU, Blue Hill, Maine. During the year I served as Chair, New England Society of American Foresters, which had 450 registrants at its Annual Winter Meeting in Portland, Maine. In the pouring rain of early September, the Austin Pond Study was the site of the CFRU Annual Advisory Committee Field Meeting, which was attended by approximately 80.

"Vegetation Management Alternatives Program, Ministry of Natural Resources, Ontario Forest Research Institute, P. O. Box 969, Sault Ste. Marie, Ontario P6A 5N5.

Figure 1. European silviculture tour group gathered at a hunter's hut in Forestry District Staufen, Black Forest, Germany. This hut is pictured in the album of Austin Gary's European forestry tour in the 1890s. Bob Frank, USDA Forest Service, can be seen on the left holding Gary's album.

Table 1. Preliminary volume summaries for seven selected plots 23 years after harvest of the site, 16 years after aerial herbicide release, and 7 years after precommercial thinning (PCT) on the Austin Pond study site.

Block No/Treatment		Trees per acre"		Avg Vol/Tree (cu ft)		Volume[1]" per acre (cu ft)		
		Fir	Spruces	Fir	Spruces	Fir	Spruces	TOTAL
5 CONTROL	PCT'd	512	96	0.49	0.39	252.71	37.44	290.15
	unPCT'd	544	238	0.39	0.36	212.63	86.90	299.53
19 CONTROL	PCT'd	487	50	1.41	0.73	690.73	36.42	727.15
	unPCT'd	272	34	0.26	0.40	69.54	13.77	83.31
9 2,4,5-T(2)	PCT'd	519	137	0.97	0.67	501.35	92.12	593.47
	unPCT'd	1105	340	0.40	0.28	446.05	95.77	541.82
21 TRIC(2)	PCT'd	567	147	1.00	0.58	569.95	86.03	655.98
	unPCT'd	2346	595	0.66	0.48	1546.57	289.03	1835.60
16 TRIC(4)	PCT'd	392	173	1.01	1.01	396.92	174.11	571.03
	unPCT'd	2244	306	0.62	0.49	1398.77	151.37	1550.14
7 GLYPHO(2)	PCT'd 'd	455	40	0 ,92	0.65	416, 37	25.84	442.21
	unPCT	1513	289	0 .55	0.44	831 69	127.86	959.55
17 GLYPHO(4)	PCT'd 'd	693	74	1 .18	0.58	821 11	43.20	864.31
	unPCT	799	85	0 .97	1.26	775 83	107.45	883.28

• Based on 100% tally of four sample plots per treatment (i.e., eight plots per numbered block) with total area sampled = 0.06 ac in the unPCT'd portions and total area sampled = 0.4 ac in the PCT'd portions of each block.

[b] Volumes based on an equation from CFRU studies of PCT'd stands by Briggs & Lemin. See Figure 2.

During the summer field season, general maintenance was completed at the Weymouth Point Study Site. Watershed borders were repainted, permanent transects were rephotographed, and the entire grid system was reviewed. This maintenance is necessary to secure the values of this area in T4R12 WELS, which has been under study since 1979. The Austin Pond Site consumed the remainder of the field effort. Under Rick Dionne's direction, forestry students Jay Horetzke and John Leighton devoted long hours to remeasuring plots. In order to complete selected tree measurements for the field tour, additional assistance was provided by Ron Lemin and forestry student Chris Beyer.

Austin Pond Study Site

This site is located in west-central Maine in Bald Mountain Township about 30 km northeast of Bingham Village. It was reviewed and documented for the Advisory Committee Field Meeting in September. Two self-guiding walking tours each about one-half mile long, were prepared. Copies of the handouts and tour guides are available for people who would like to review the plot results at their own convenience. The plots are within an area managed by Scott Paper Company and are now 23 growing seasons after harvest, 16 growing seasons after the application of the herbicide study treatments, and 7 growing seasons after an operational precommercial thinning (PCT). Plots are approximately 1 ha in size with half of each treated with PCT. Seven of the 22 plots suitable for remeasurement were completed prior to the field tour. The plots selected for remeasurement were intended to represent a range of conditions from untreated to what was considered to be silviculturally effective herbicide treatments. A 2,4,5-T treatment was included because, visually, it appeared to be an intermediate condition. The summary of spruce and fir trees/ac and volumes for the seven plots is shown in Table 1. Volumes are based on an equation from CFRU studies conducted by Briggs and Lemin summarized in the Site Quality section of this Annual Report. Austin Pond Site study trees are plotted over the equation in Figure 2.

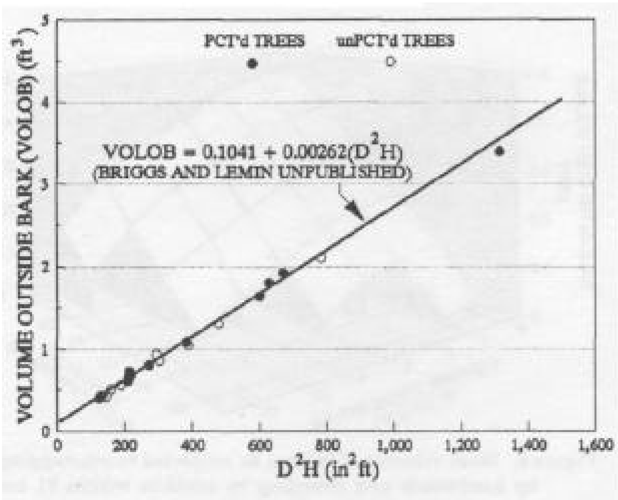

Figure 2. Austin Pond Site study trees, with and without precommercial thinning, plotted over the volume equation of Briggs and Lemin described in the Site Quality section of this Annual Report. It supports the use of this equation for the site.

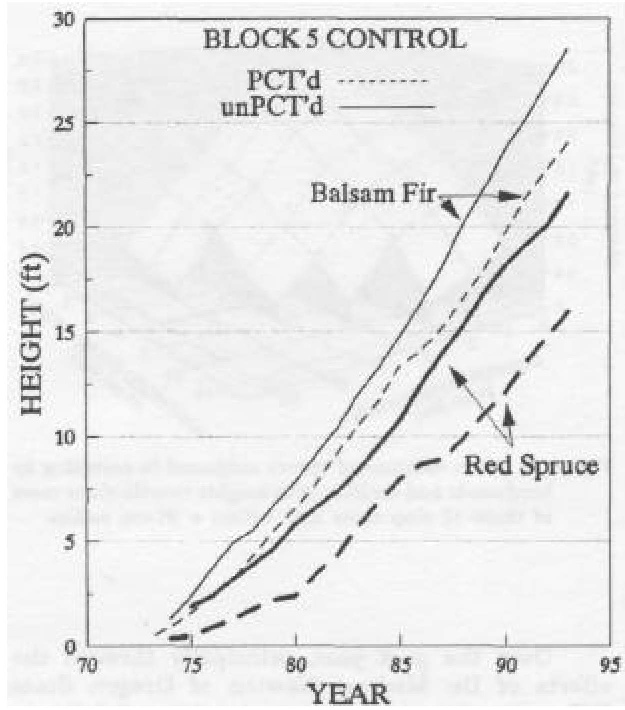

Figure 3. Height growth over the study period for precommercially thinned and unthinned spruce and fir study trees in Austin Pond Study Plot 5, no release with herbicide.

The values in Table 1 indicate the following conditions:

(1) Total stand volumes of spruce-fir are highest in the stands treated with herbicide, but not precommercially thinned.

(2) Total stand volumes of spruce are highest in stands treated with herbicide, but not precommercially thinned.

(3) Highest average volumes per spruce tree and per fir tree are in stands treated with herbicide with precommercial thinning.

(4) In stands without herbicide treatment, or with lower levels of herbicide efficacy, the highest stand volumes are in the stands that were precommercially thinned.

Some selected data from the stem analyses are shown in Figures 3 and 4. These illustrate height growth over the study period for precommercially thinned and unthinned firs and spruces. There are consistent patterns reflected in these data. However, the picture is not complete without considering radial growth, which has been greater in the released plots. This relationship can be seen in the average volumes per tree shown in Table 1. Further field work and measurements should provide more details and understanding. Currently, crown biomass is being evaluated from samples taken during the work on the stem analysis sample trees.

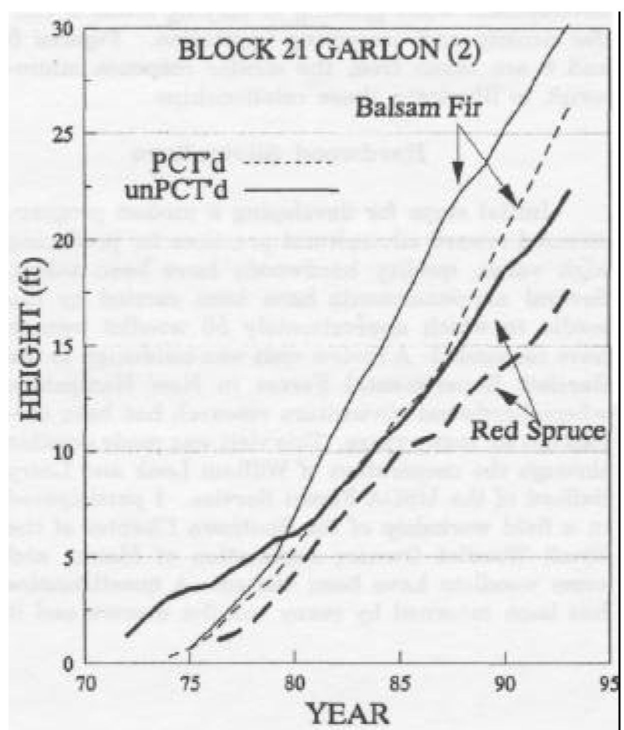

Figure 4. Height growth over the study period for precommercially thinned and unthinned spruce and fir study trees in Austin Pond Study Plot 21, released with 2 Ibs ai/ac of triclopyr amine.

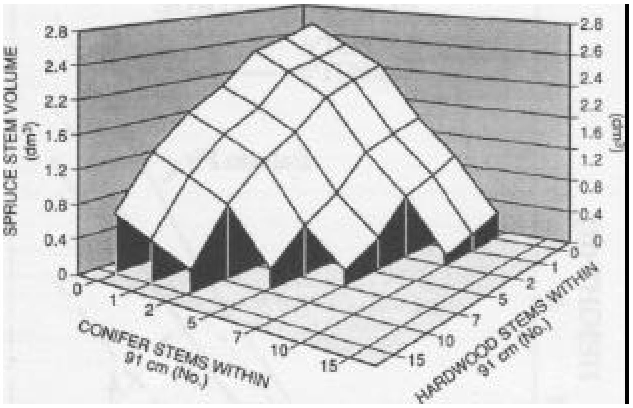

Figure 5. Stem volumes of spruce subjected to crowding by hardwoods and conifers with heights two-thirds or more of those of crop trees and within a 91-cm radius.

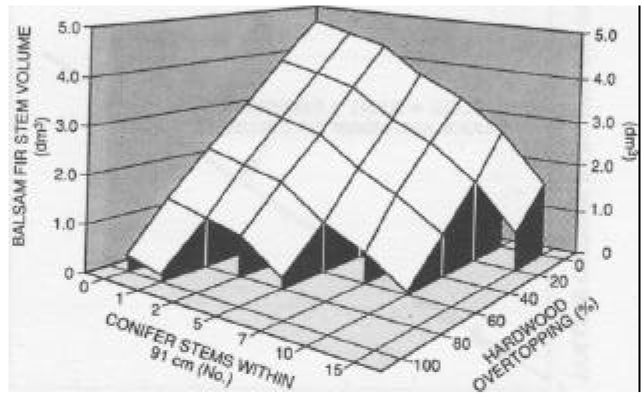

Figure 6. Stem volumes of balsam fir subjected to overtopping by hardwoods and crowding by conifers within 91 cm and with heights two-thirds or more of those of crop trees.

Over the past year, principally through the efforts of Dr. Michael Newton of Oregon State University, the nine-year results from the Austin Pond Site were published. These results report conditions during earlier development periods than the work presently under way. The reported data show general relationships, rather than those specific to herbicide treatments, for spruce and fir crop tree development while growing in varying levels of conifer density and competing vegetation. Figures 5 and 6 are taken from the conifer response manuscript to illustrate these relationships.

Hardwood Silviculture

Initial steps for developing a modest program directed toward silvicultural practices for producing high value, quality hardwoods have been taken. Several announcements have been carried by the media to which approximately 50 woodlot owners have responded. A review visit was conducted to the Bartlett Experimental Forest in New Hampshire where hardwood silviculture research has been carried out for many years. This visit was made possible through the cooperation of William Leak and Larry Safford of the USDA Forest Service. I participated in a field workshop of the Southern Chapter of the Small Woodlot Owners Association of Maine, and some woodlots have been visited. A questionnaire has been returned by many woodlot owners and it is planned to distribute additional copies in order to obtain more background information about conditions and interests.

Over the coming year, as time and resources permit, the following activities will be pursued:

(1) Assessment of conditions, interests, and needs relative to production of high-value, quality hardwood species.

(2) Assemble and summarize existing, applicable information and experiences that will be help ful and informative for landowners interested in producing high-value hardwood trees for profit.

(3) Focus attention on the potential for producing high-value hardwood species on suitable sites in Maine.

(4) Establish field plots for demonstration and for the collection of needed data on silvicultural options and growth and development of hard wood crop trees.

(5) Develop a plan for woodlot owners to establish small plots to monitor species composition, regeneration, and development of valuable hardwood species on their woodlots.

ASH RESIDUE UTILIZATION AND TIMBER QUALITY IMPROVEMENT

Dr. William D. Ostrofsky

Introduction

The majority of the research effort this year was spent on monitoring and sampling the two papermill sludge ash application studies established over the past two years. Due to the relatively high cost of both plant and soil sample analyses, no summer field technicians were hired this year. CFRU Research Associate P. Caron and graduate student Y. Ren conducted the majority of the field work. No new research projects •were initiated this year.

A one-day conference on forest land spreading of papermill sludge, sludge ash, and wood and bark ash residuals was held in early May. Most industry cooperators involved with sludge and ash residuals management were represented, and several scientists from the university community provided updates on current research activities. This effort helped focus the research priorities, and the information is being used to update the problem analysis now being drafted for this program. Several research areas were identified by the group as being of most critical concern. The effects of residual materials on competing vegetation, the application of residuals to partially cut stands, and the quantification and effects of heavy metals, particularly cadmium, in some ash materials, are of most concern.

The M.S. project on effects of papermill sludge ash on soil microbial activity conducted by Y. Ren is planned for completion by May of 1994. A new graduate student is expected to arrive in January to begin working on a M.F. program, on a topic to be defined during the coming winter.

In October of 1992, a symposium was held in conjunction with the 50th anniversary of the Maine Hardwood Association. The Symposium, entitled "What's Ahead for Maine's Hardwood Resource" focused on new wood-processing technologies and featured several USDA Forest Service speakers from hardwood research labs in Virginia and West Virginia. Dr. L. Safford, USDA Forest Service, Durham, N.H., and I served as co-chairs of the meeting, and approximately 60 people attended. The proceedings of the meeting are forthcoming.

Papermill Sludge Ash Utilization - King and Bartlett Township

Monitoring of soil characteristics and tree growth continued on this site, located on International Paper Company lands, where four application rates (0, 2, 4, and 6 tons $CaCO_3$ equivalent per acre) of papermill sludge ash were applied in 1991 to plots of planted black spruce. Some initial results of the one-year post-treatment analysis of forest floor is shown in Table 2. Statistically significant increases in pH, Ca, and P occurred with increasing rates of ash application, while Al, Fe, Mn, and TKN decreased with increasing rate. K also showed a trend to

Table 2. Elemental analysis of the forest floor one year following papermill sludge ash application at the King and Bartlett Township study site. Values represent the mean of eight replicate samples.

Block		pH	Ca	K	Mg	Al	Fe	Mn	Na		TKN
			rag/kg dry soil -								%
1	Untreated	4.5	2885	498	298	216	30	380	46	61	1.40
	2 tons/acre	5.0	4703	549	375	134	8	335	57	74	1.31
	4 tons/acre	6.4	7089	491	347	28	8	166	62	104	0.71
	6 tons/acre	6.3	6889	394	321	31	9	131	51	70	0.71
	Uncut Forest	3.8	1632	576	201	488	68	75	71	97	1.22
2	Untreated	4.3	1704	418	190	570	36	200	39	50	1.57
	2 tons/acre	5.2	3808	377	250	160	17	159	46	36	1.02
	4 tons/acre	5.7	4455	400	268	83	5	134	46	55	1.01
	6 tons/acre	6.2	5676	362	266	33	8	120	49	80	0.61
	Uncut Forest	3.8	1027	495	129	688	71	50	22	63	1.19

[a] Tons calcium carbonate equivalent per acre applied in the form of papermill sludge ash in July 1991.

Table 3. Elemental analysis of the mineral soil one year following papermill sludge ash application at the King and Bartlett Township study site. Values represent the mean of eight replicate samples.

Block	^reat-	pR	Ca	K	Mg	Al	Fe	Mn	Na			TKN
			ng/kg dry soil									%
1	Untreated	4.5	70	55	10.4	284	21	8.0	3.0		7.9	0.161
	2 tons/acre	4.5	89	70	13.6	305	29	6.6	4.5		7.7	0.206
	4 tons/acre	4.5	124	74	15.6	362	31	8.1	6.0		8.2	0.238
	6 tons/acre	4.7	133	96	17.5	307	16	6.4	4.0		10.0	0.266
	Uncut Forest	4.5	55	37	9.0	233	15	3.4	7.2		7.1	0.107
2	Untreated	4.5	79	59	11.0	376	20	7.1	4.2		10.8	0.228
	2 tons/acre	4.5	102	60	13.5	366	22	7.4	4.5		9.1	0.235
	4 tons/acre	4.6	166	82	18.7	313	20	14.1	6.0		9.4	0.265
	6 tons/acre	4.5	185	59	20.0	372	28	5.9	6.7		8.3	0.256
	Uncut Forest	4.4	40	37	9.6	297	18	5.6	6.2		7.8	0.151

Tons calcium carbonate equivalent per acre applied in the form of papermill sludge ash in July 1991.

decrease with increasing rates, but the difference was not significant. Elemental trends were often reflected in the mineral soil, where losses from forest floor resulted in increased concentrations (for example, Al) in the mineral soil (Table 3).

Analyses are now focusing on differences in elemental concentrations between blocks and between mineral soil that was either exposed at the time of sludge ash application, or undisturbed under intact forest floor. For example, Ca concentrations in exposed mineral soil were found to increase significantly with increasing rate of sludge ash in Block 1 (slightly better drained than Block 2), but peaked at the 4-ton (moderate) application rate in Block 2. Concentrations of Ca were also less, overall, in Block 2.

Conversly, Al concentrations significantly decreased with increasing rates of sludge ash applied to exposed mineral soil in Block 1, but remained constant in Block 2. Further analysis of interactions of block, treatment, and soil disturbance will help to clarify the complexity and potential variability that may be expected from site to site.

Analysis of current-year black spruce foliage showed significant increases in Ca and Mg with increasing rates of application one year after treatment (Table 4). A slightly different response was shown by raspberry foliage. Here, Ca and P increased with increasing rates of application (Table 5). These results indicate the variability with which different species respond to the ash materials.

Black spruce height growth has apparently not been affected by ash application. Only trees in the moderate rate treatment (4 tons/acre $CaCO_3$ equivalent) of Block 2 showed increased height growth (Figure 7). The plots (with the rest of the plantation) were given a second herbicide treatment in the late summer of 1993, so competition effects of unwanted vegetation should be minimized.

Two-year post-treatment forest floor and mineral soil samples were collected from the 16 treated plots, and from four additional plots established in the adjacent, uncut forest stand, and were submitted for elemental analysis. This year, to save costs, the four forest floor samples and the six mineral soil samples collected from each plot were composited by plot before submitting for analysis. This reduced the number of individual analyses from 192 to 56.

Black spruce foliage samples were collected for elemental analysis at the end of the 1993 growing season, and the trees were again measured for height and diameter growth. Results of the two-year post-treatment soil and foliage sampling will not be available until spring of 1994.

Table 4. Elemental analysis of current-year black spruce foliage one year following application of papermill sludge ash to the King and Bartlett Township study site.

Treatment[8]	N	Ca[b]	K	Mg[b]	P	Al	B	Cu	Fe	Mn	Zn
Untreated	2.32	5342	5392	830	2162	71	24	5.6	60	1,227	73
2 tons/acre	2.15	5545	5805	996	2200	70	23	5.3	58	1,160	80
4 tons/acre	2.16	5912	5347	943	2167	60	25	5.4	60	1,157	76
6 tons/acre	2.02	6455	5632	1086	2170	56	24	5.1	58	1,097	88

Tons of calcium carbonate equivalent per acre, applied in the form of papermill sludge ash in July, 1991. Dry weight values are means from two replicate plots from each of two blocks.

Statistically significant difference (P<0.01) between treatments.

Table 5. Elemental analysis of raspberry foliage one year following application of papermill sludge ash to the King and Bartlett Township study site.

Treatment[4]	N	Ca[c]	K	Mg	P[b]	Al	B[c]	Cu[c]	Fe	Mn	Zn
Untreated	2.67	8135	11550	3057	2937	47	39	8.6	64	1262	44
2 tons/acre	2.52	9997	11800	3527	3545	44	47	7.3	66	1222	46
4 tons/acre	2.64	9787	12650	3390	3960	36	46	7.1	66	1172	39
6 tons/acre	2.49	10837	11975	3502	4002	42	47	7.3	64	1122	35

Tons of calcium carbonate equivalent per acre, applied in the form of papermill sludge ash in July, 1991. Dry weight values are means from two replicate plots from each of two blocks.

Statistically significant difference (P<0.01) between treatments. [0]

Statistically significant difference (P<0.05) between treatments.

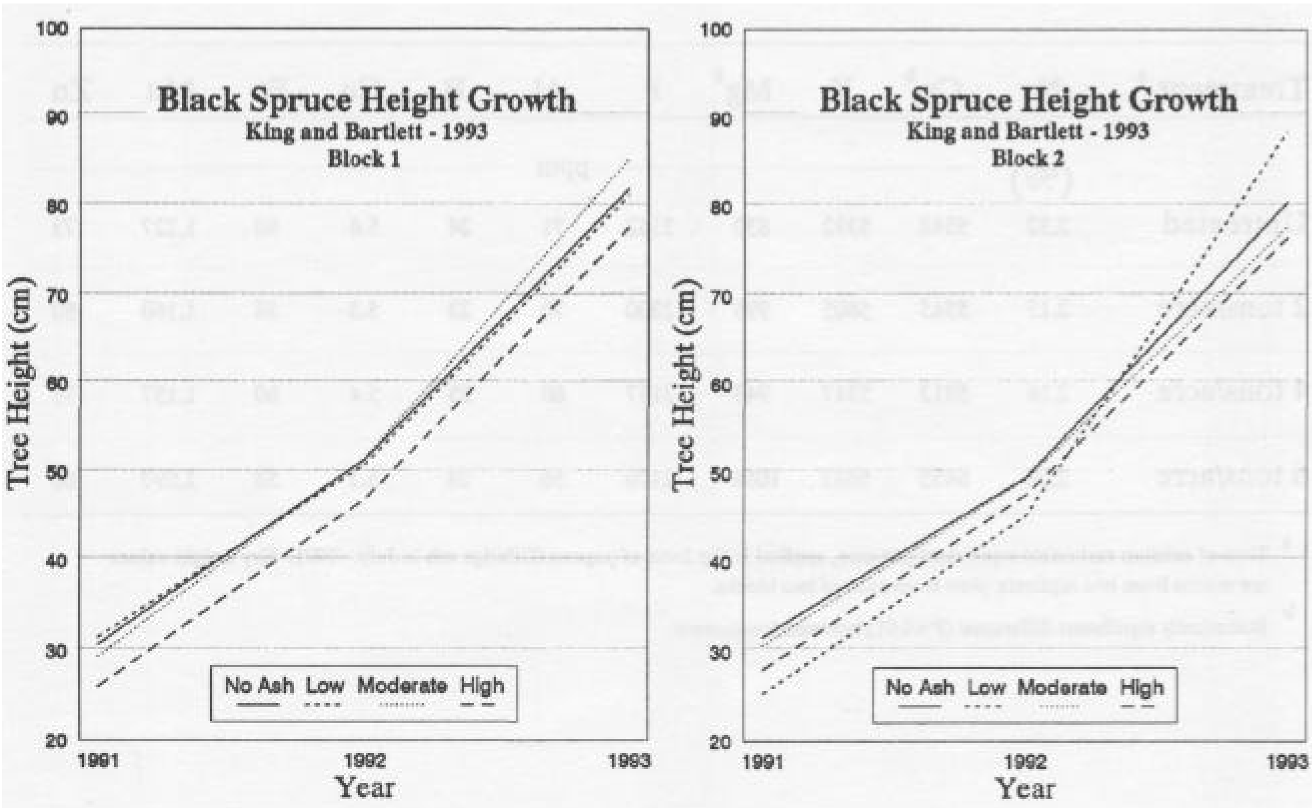

Figure 7. Black spruce height growth at the King and Bartlett Township study site. Papermill sludge ash was applied to the site after the 1991 (pre-treatment) measurements were obtained.

Extensive soil sampling is not planned for the 1994 season, but foliage sampling likely will continue. It would be appropriate to sample soils at a regular interval of perhaps every three to five years, depending on available resources. Growth of competing vegetation should also be monitored as the plantation develops.

Wood Ash and Papermill Sludge Ash Utilization - Heald Pond

The Heald Pond study site, located on Scott Paper Company lands in Caratunk Tbwnship, was established in 1992 and consists of 48 plots each containing nine planted red pine and nine sugar maple seedlings (or sprouts) of natural origin. Half the plots were treated with papermill sludge ash and half with wood ash (at 0, 3, 6, or 9 tons $CaCO_3$ equivalent per acre) in late summer of 1992. In addition, six untreated plots were also established in an adjacent, uncut forest area to provide additional baseline soils data. Soil characteristics (Figure 8) and tree growth were monitored during this first year after treatment. Red pine and sugar maple foliage was collected and submitted for elemental analysis. Results of the soil and plant tissue

Figure 8. Appearance of the soil profile in a sample pit at the Heald Pond study site. Forest floor and mineral soil samples were composited from five pits for each plot.

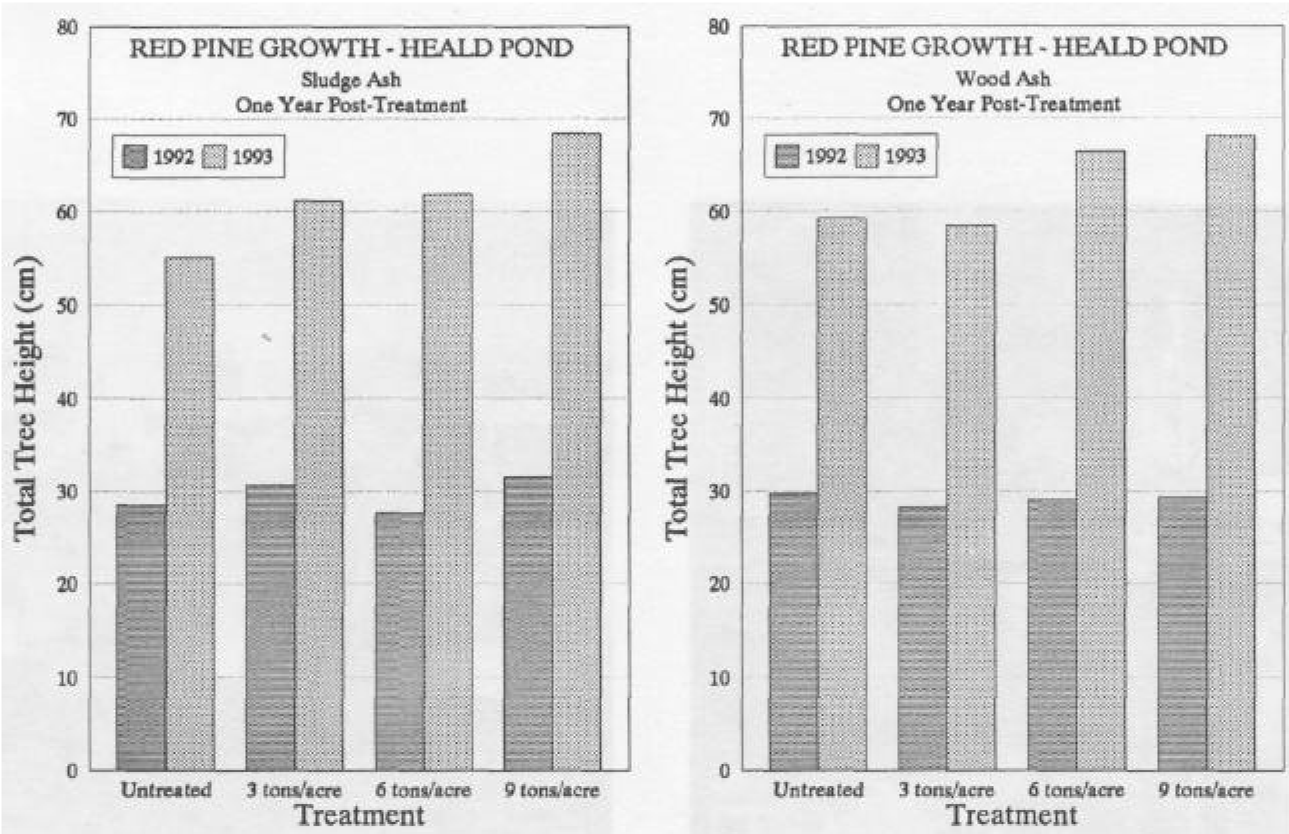

Figure 9. Red pine height growth at the Heald Pond study site. Ash materials were applied to the site after the 1992 (pre-treatment) measurements were obtained.

analyses should be available by spring of 1994. Brush saws were again used in late summer to reduce the effects of competing vegetation in the 48 treated plots.

Preliminary analysis indicated slight differences in height growth of red pine between treatments one year after ash application (Figure 9). Trends suggested that red pine treated with either 6 or 9 tons $CaCO_3$ equivalent per acre of wood ash also had slightly increased height growth. Additional statistical evaluations will be conducted over the next several months.

The analysis of sugar maple height growth has been complicated by browsing and dieback. Over 26% of the sugar maple have been browsed, and an additional 10% have experienced some shoot dieback. The dieback was likely intensified by the dry weather conditions this past summer. There is no apparent relationship of browsing to ash treatment; 25% of the sugar maple in control (untreated) plots were browsed, and 10% sustained dieback.

Effects of Papermill Sludge Ash on Forest Soil Microbiology

Y. Ren continued her M.S. project on isolation and characterization of soil microbes as affected by various $CaCO_3$ equivalent rates of papermill sludge ash (Figures 10 and 11). Soil sampling was done monthly from May through October at the Heald Pond study site. Data collection and analysis is continuing, but some preliminary findings are reported here.

Soil (forest floor) microbial biomass carbon was not found to be significantly different between treatments, at least during the first three months of sampling (Figure 12). No seasonal changes are evident as yet either, but changes may be observed when the full complement of monthly data becomes available.

Tb assess changes in microbe populations, soil bacteria were isolated using soil extract agar. The data indicate that numbers of bacteria are

Figure 10. Graduate student Taping Ren prepares to isolate microorganisms from the soil samples, collected monthly from May through October 1993.

Figure 11. Forest floor samples set up for determination of microbial activity.

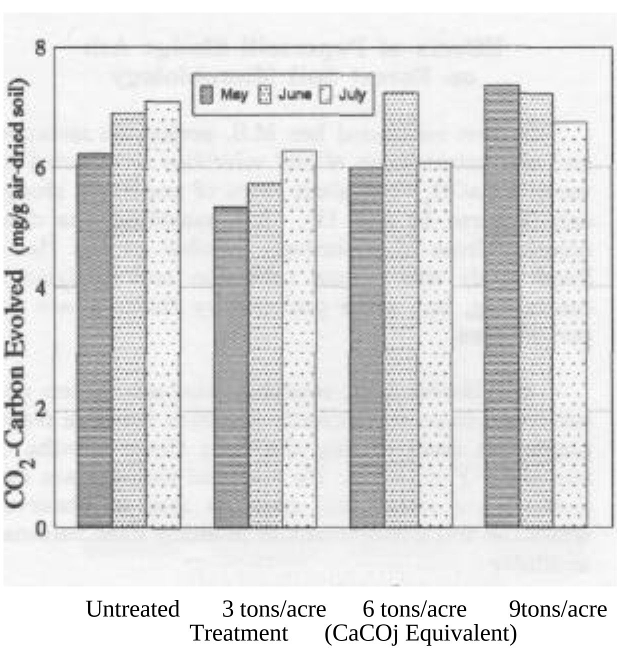

Figure 12. Estimated levels of microbial biomass carbon in the forest floor at the Heald Pond study site during the 1993 growing season, from nine through eleven months post-treatment.

significantly different between treatments (Figure 13). Bacterial numbers were lowest in forest floor soil from the uncut forest plots. The bacterial numbers were found to increase continuously from lower to higher rates of sludge ash application. This is probably a result of the increasing pH, allowing for more suitable conditions for bacterial development. A seasonal trend is also apparent. Highest bacterial numbers were observed in the early spring and decreased in the plots as the season progressed, with the exception of the uncut forest plots.

Fungi were isolated from the forest floor using malt extract agar (Figure 13). Data indicate a different population trend than that observed for bacteria. There were no significant differences in numbers of fungi between treatments, again with the exception of the uncut forest plots. Populations of fungi in the uncut forest plots were lower than those in the clearcut and planted plots. Similar to the bacterial population trends, numbers of fungi isolated decreased as the season progressed from spring through summer.

Uncut Forest Untreated 3 Tons/Acre 6 Tons/Acre 9 Tons/Acre

Treatment ($CaCO_3$ Equivalent)

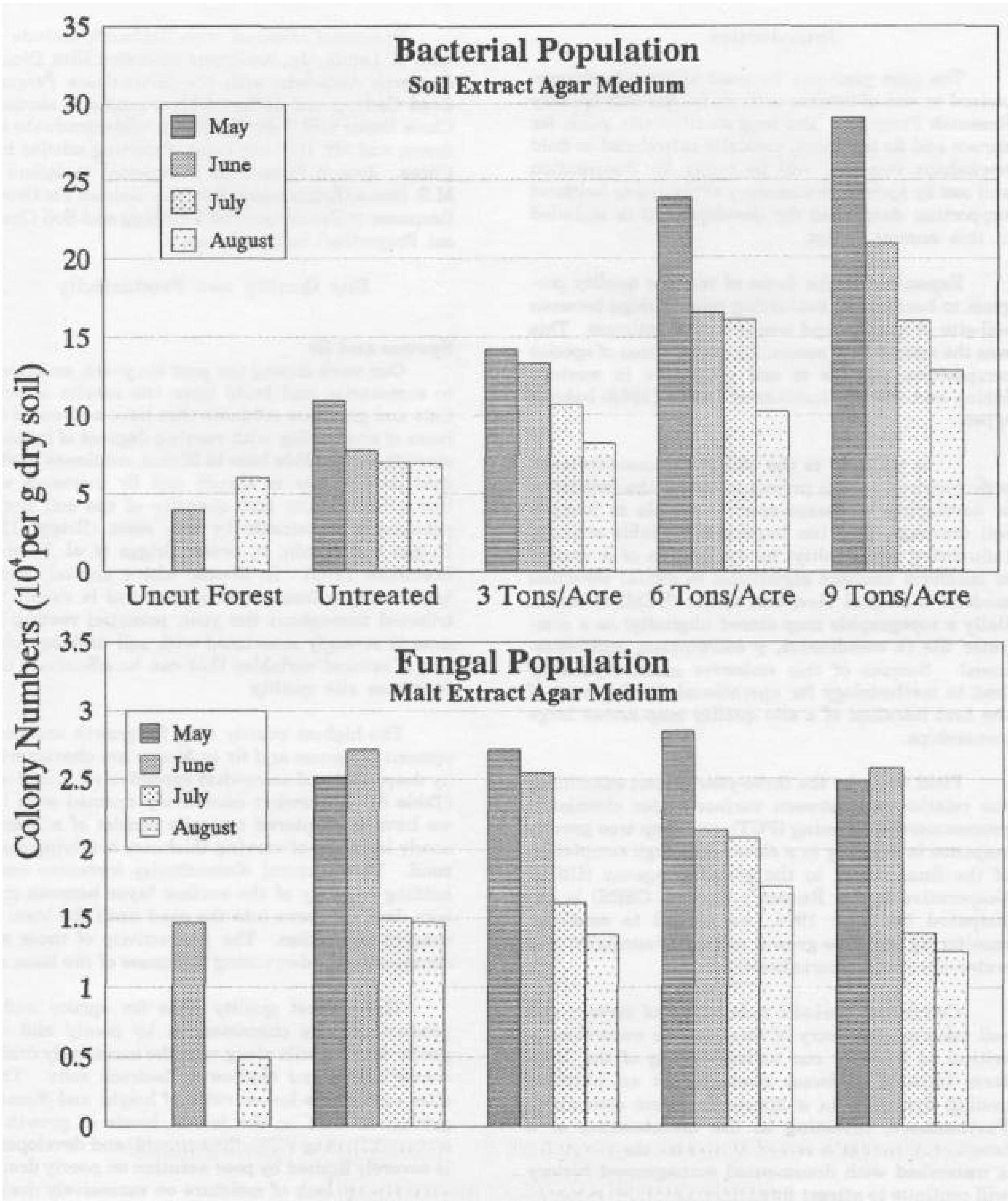

Figure 13. Populations of bacteria and fungi in forest floor samples from the Heald Pond study site during the 1993 growing season, from nine through twelve months post-treatment.

Analysis of the data is continuing, as the final months of sampling are concluded. Additional information on microbe identification and species changes with treatment and with season will be forthcoming. The project is scheduled for completion by May 1994.

SITE QUALITY

Dr. Russell D. Briggs

Introduction

The past year can be most accurately characterized as one of intense activity for the Site Quality Research Program. The long awaited site guide for spruce and fir in Maine, partially introduced in field workshops this fall, will be ready for distribution and use by spring. A summary of the guide (without supporting data used for development) is included in this annual report.

Expansion of the focus of the site quality program to hardwoods, evaluating relationships between soil-site properties and tree growth, continues. This was the second field season for examination of species composition relative to soil properties in western Maine and the applicability of Leak's (1982) habitat types.

In addition to the biological considerations, we embarked upon a project to assess the feasibility of developing landscape-specific models to identify soil drainage class (an important variable strongly influencing site quality) by application of a variety of landform analysis algorithms to digital elevation models. A digital elevation model (DEM) is essentially a topographic map stored (digitally) as a computer file (x coordinates, y coordinates, and elevations). Success of this endeavor could ultimately lead to methodology for operational development of the first iteration of a site quality map across large ownerships.

Field work for the three-year project examining the relationship between surface water chemistry, precommercial thinning (PCT), and crop tree growth response is drawing to a close. Although completion of the final report to the granting agency (USDA Cooperative States Research Service, CSRS) is anticipated by June 1994, we intend to continue monitoring crop tree growth response (annually) and water chemistry (periodically).

Continued, periodic monitoring of stream and soil solution chemistry of this historic watershed is critical to increase our understanding of the long-term impacts of forest management on nutrient cycling dynamics in a spruce-fir forest ecosystem. Furthermore, investing in the maintenance of a temporally complete record of stream chemistry for a watershed with documented management history will continue to attract financial support for research in the future. It is worthwhile to point out that the availability of the water chemistry record at the Weymouth Point watershed for 1979-1988, in existence due to the efforts of Drs. Maxwell McCormack and C. Tattersall Smith, was an important contributing factor to our success in obtaining funding for the current study.

Personnel involved with fieldwork include Ronald C. Lemin, Jr., Assistant Scientist; Rick Dionne, Research Associate with the Silviculture Program; Brad Catling and Jeffery Dubis, graduate students; Chris Beyer and John Leighton, undergraduate students; and Mr. Huilong Fang, a visiting scholar from China. Joseph Pitcheralle is expected to defend his M.S. thesis (Relationship Between Balsam Fir Growth Response to Precommercial Thinning and Soil Chemical Properties) before January.

Site Quality and Productivity

Spruce and fir

Our work during the past six years, an attempt to summarize and build upon the results of scientists and graduate students that have addressed this issue of site quality with varying degrees of intensity since the mid-1950s here in Maine, continues to show that productivity of spruce and fir increases with increasing quality and quantity of the soil that is potentially exploitable by tree roots (Briggs 1989; Briggs and Lemin, in press; Briggs et al. in press; Steinman 1992). In Maine, where annual precipitation ranges from 41-45 inches and is evenly distributed throughout the year, potential rooting volume is strongly associated with soil drainage class, one of several variables that can be effectively used to assess site quality.

The highest quality sites for growth and development of spruce and fir in Maine are characterized by deep, well and somewhat excessively drained soils (Table 6). Somewhat excessively drained soils that we have encountered typically consist of a loam or sandy loam cap of varying thickness overlying coarse sand. This textural discontinuity increases water-holding capacity of the surface layer because moisture does not move into the sand until the loam cap reaches saturation. The productivity of those soils decreases with decreasing thickness of the loam cap.

The poorest quality sites for spruce and fir productivity are characterized by poorly and very poorly drained soils along with the excessively drained coarse sands and shallow to bedrock soils. Those sites exhibit the lowest rates of height and diameter growth as well as the lowest levels of growth response following PCT. Root growth and development is severely limited by poor aeration on poorly drained soils and by lack of moisture on excessively drained soils. The complete site classification guide will illustrate the magnitude of the differences in tree growth across site classes.

At the present time, the site classification system relies solely on easily measured soil physical variables: drainage class, potential rooting depth,

Table 6. Proposed site classification for the productivity of spruce and fir in Maine, September 1993. Site class 1 is the most productive and site class 5 is the least productive.

	Site Class							
	1		2		3		4	5
	Well Drained	Somewhat Excessively Drained	Somewhat Excessively Drained	Moderately Well Drained	Somewhat Excessively[1] Drained	Poorly Drained	Poorly Drained	Very Poorly Drained
Mottling Depth[2]:	>24"	>24"	>24"	16-24"	8-16"	4-8"	None	<4
Thickness Loam Cap:	—	>12"	8-12"	-	-			

[1] Shallow to bedrock (<12") or coarse sand and gravel.
[2] Depth to the seasonal high water table is indicated by depth to low chroma mottles (or gley).

and field determination of soil texture (sand vs. loams and silt loams). Analysis of the soil chemical data collected from the study plots established in precommercially thinned stands (Pitcheralle, in preparation) may result in further refinements. Results from his analyses show that, after accounting for the effects of soil drainage class, soil chemical and forest floor variables are associated with balsam fir response to PCT. Stepwise regression indicated that forest floor thickness combined with B horizon organic matter, percent silt, and exchangeable potassium accounted for 52% of the variation in residuals for predicted vs. actual 3-year post-PCT volume increment. We continue to explore these results to identify a practical application in assessment of site quality.

Detailed stem analysis of more than 500 spruce and fir trees growing in precommercially thinned stands across Maine provided us with an opportunity to develop volume equations for young trees growing in managed stands. Using height and dbh (diameter outside bark at 4.5 ft), total volume inside and outside bark can be accurately estimated for these small trees, providing a more accurate assessment of growth response. The volume equation is illustrated for the range of dbh and total heights used for its development (Figure 14). The detailed procedure used for model development is currently in the publication process and will be available in the near future as a CFRU Research Note.

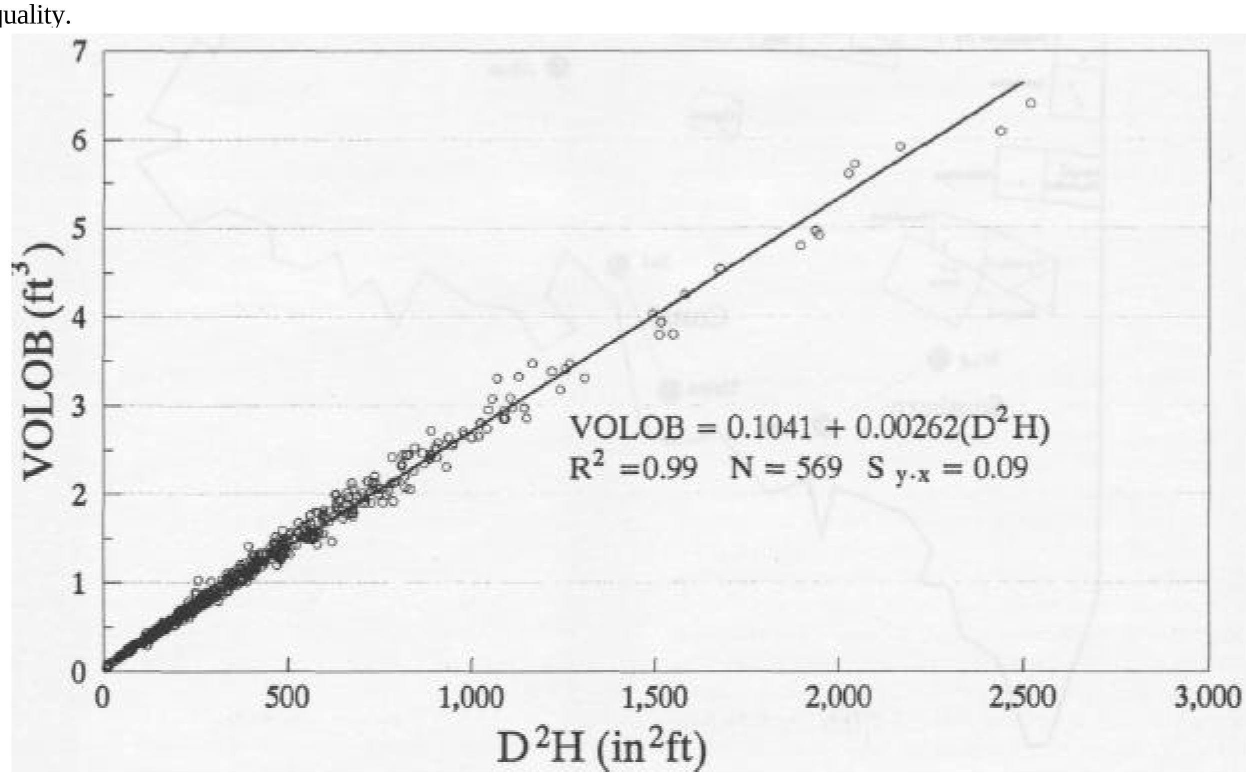

Figure 14. Volume equation for young spruce and fir growing in managed stands.

Hardwoods

Species composition

Jeff Dubis, M.S. candidate, has completed the second year of field sampling focused on addressing (i) the applicability of Leak's (1982) habitat classification to conditions in the western mountain biophysical region, and (ii) the relationship between species composition, topography, and soil physical properties.

During the summers of 1992 and 1993, 126 0.20-ac and 8 0.10-ac plots were established in the western mountain biophysical region (McMahon 1990) in closed canopy stands that had not been entered for harvest within the past 20 years (Figure 15).

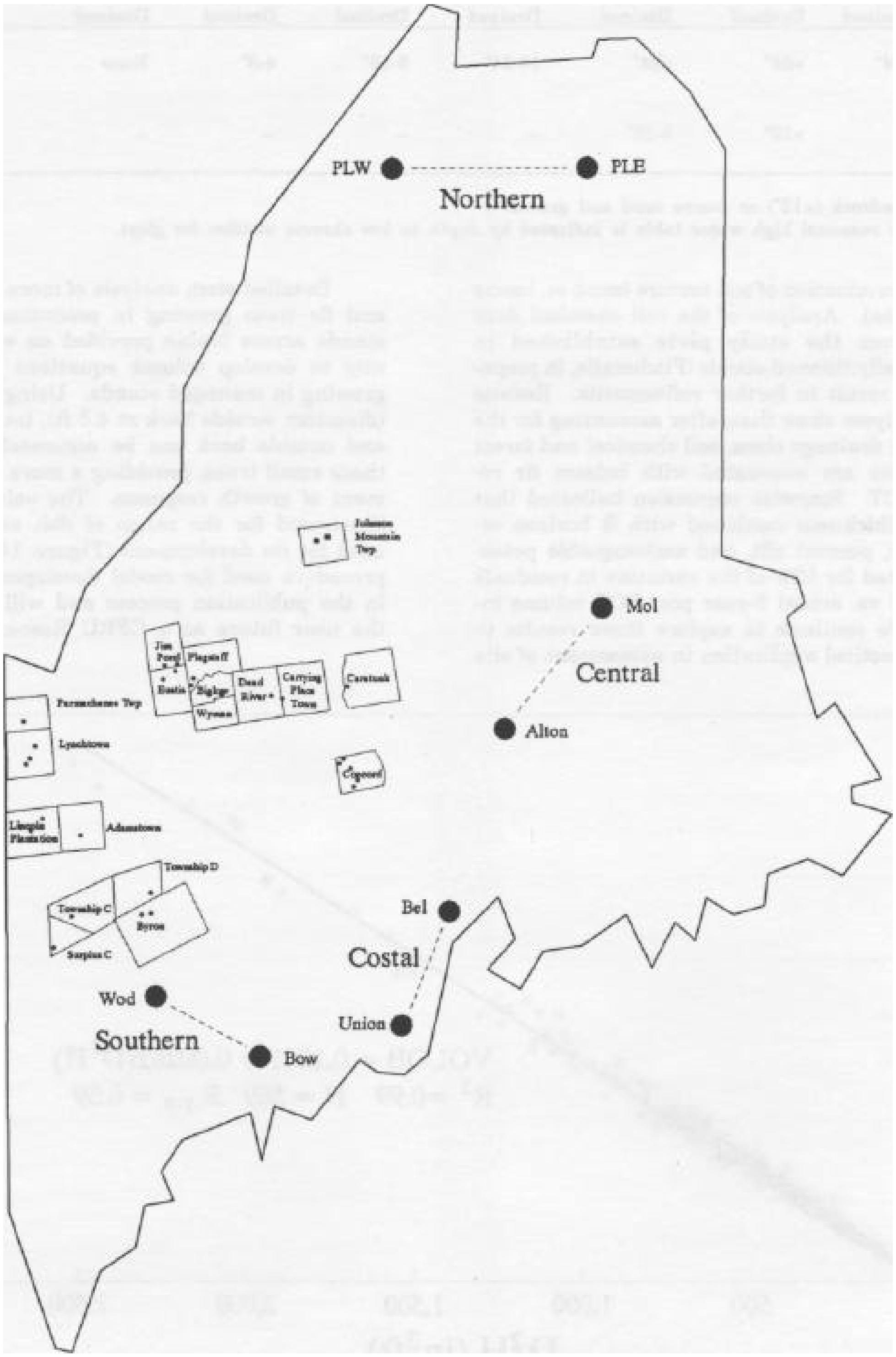

Figure 15. Map of Maine illustrating relative locations of the sample plots established in western Maine during the 1992-1993 field seasons, locations of research areas in Johnson Mt. Township, and four transects spanning climatic regions (indicated with a dashed line).

Table 7. Distribution of sample plots by habitat type and soil drainage class.

Habitat Type[1]	No. of Plots	Drainage Class	No. of Plots
Dry Compact Till	34	Poorly Drained	8
Fine Till	7	Somewhat Poorly Drained	12
Fine Till over Pan	29	Moderately Well Drained	50
Enriched	7	Well Drained	55
Shallow to Bedrock	15	Somewhat Excessively Drained	1
Loose Rock	4	Excessively Drained	8
Coarse Washed Till	5		
Outwash	9		
Sandy Sediment	7		
Wet Compact Till	11		
Fine Washed Till	2		
Total	130		134

[1] Four plots could not be classified by habitat type.

The 1993 plots were established to sample habitat types that had been poorly represented in the 1992 sample (sediments, outwash, and fine tills). William Leak spent two days with us to ensure that our interpretations of habitat types described in his publication (Leak 1982) were accurate. The distribution of sample plots by habitat type and soil drainage class is provided in Table 7.

Two dominant or codominant stems for each species present on a plot were selected for the measurements of radial increment (increment core) at bh and total height. Seedlings and saplings were tallied by species in 1" dbh classes along a six-foot-wide strip extending across the plot through plot center. Herbaceous vegetation was recorded by percent cover classes for each species.

Comparison of the basal area distribution by species between habitats in the White Mt. National Forest and corresponding habitats sampled in Maine revealed substantial differences. For many habitat types sampled in Maine, sugar maple constituted a greater portion of the stand basal area than for the corresponding habitat type in New Hampshire; basal area distributions for the shallow to bedrock and the dry compact till habitats illustrate the magnitude of the differences (Figure 16).

Analysis of the data is in the early stages and will culminate with the production of a thesis in the latter half of 1994.

Assessing soil drainage class using digital elevation models

Brad Catling, candidate for a M.S. degree, is working on a project to develop a statistically calibrated computer model to predict soil drainage class based on topography as described by a USGS digital elevation model (DEM). Ultimately, this could lead to methodology for production of the first iteration of an operational site classification map. The field work was done in Johnson Mt. Township, due to the availability of the USGS 7.5 minute DEM (1:24,000 scale, 30 m accuracy) and SCS order III soil maps.

Two areas, approximately 1 square mile each, were selected in Johnson Mt. Township for study (Figure 15). Both areas, hilly with elevations up to 3000 ft, were located between the major mountain peaks. Assessing soil drainage class from ridge top to valley floor along the major peaks is relatively easy. The real challenge lies in the middle elevations of the smaller mountains and rolling hills between major peaks. A grid (10 chain X 10 chain) was established in each sample area to distribute sample points across the landscape from hill top to local valley.

Sixty-six plots were located in one area and 56 plots (limited by large gravel pit and nearby swamp) were located in the second area. A soil pit was excavated at each plot and soil drainage class, depth to mottling, depth to root restricting layer, and thickness of each horizon were recorded. The position of each sample point was established using a global positioning system (GPS).

Data analysis is in the very early stages. Topographic variables that are being evaluated from the DEM include slope gradient, slope shape, midslope position, proximity to drainageway, and aspect. Classification tree analysis will be used to develop a model relating soil drainage class to topographic variables. Following model development, drainage class will be predicted for each pixel.

In order to illustrate the nature of the spatial database, flow accumulation was estimated from the DEM as a function of slope shape, gradient, and relative position, using an algorithm in ARCINFO. The relative amount of water that will accumulate at a given position is an important factor influencing soil drainage class. A two-dimensional illustration of potential water accumulation overlaid with sample point locations is provided in Figure 17. Maximum water accumulation is denoted by dark and minimum water accumulation is indicated by light shading.

Precommercial Thinning and Soil Solution Chemistry

The water quality study, funded by the USDA Cooperative States Research Service, is entering the final year. The objectives of this study are (i) to examine the effects of precommercial thinning on soil solution chemistry and crop tree growth, and (ii) to evaluate the relationship between the ground water systems above and below the basal till. Groundwater depth and chemistry is being monitored in seven wells (8 to 30 ft below ground surface). Samples continue to be collected monthly from streams passing through the control and clearcut watersheds.

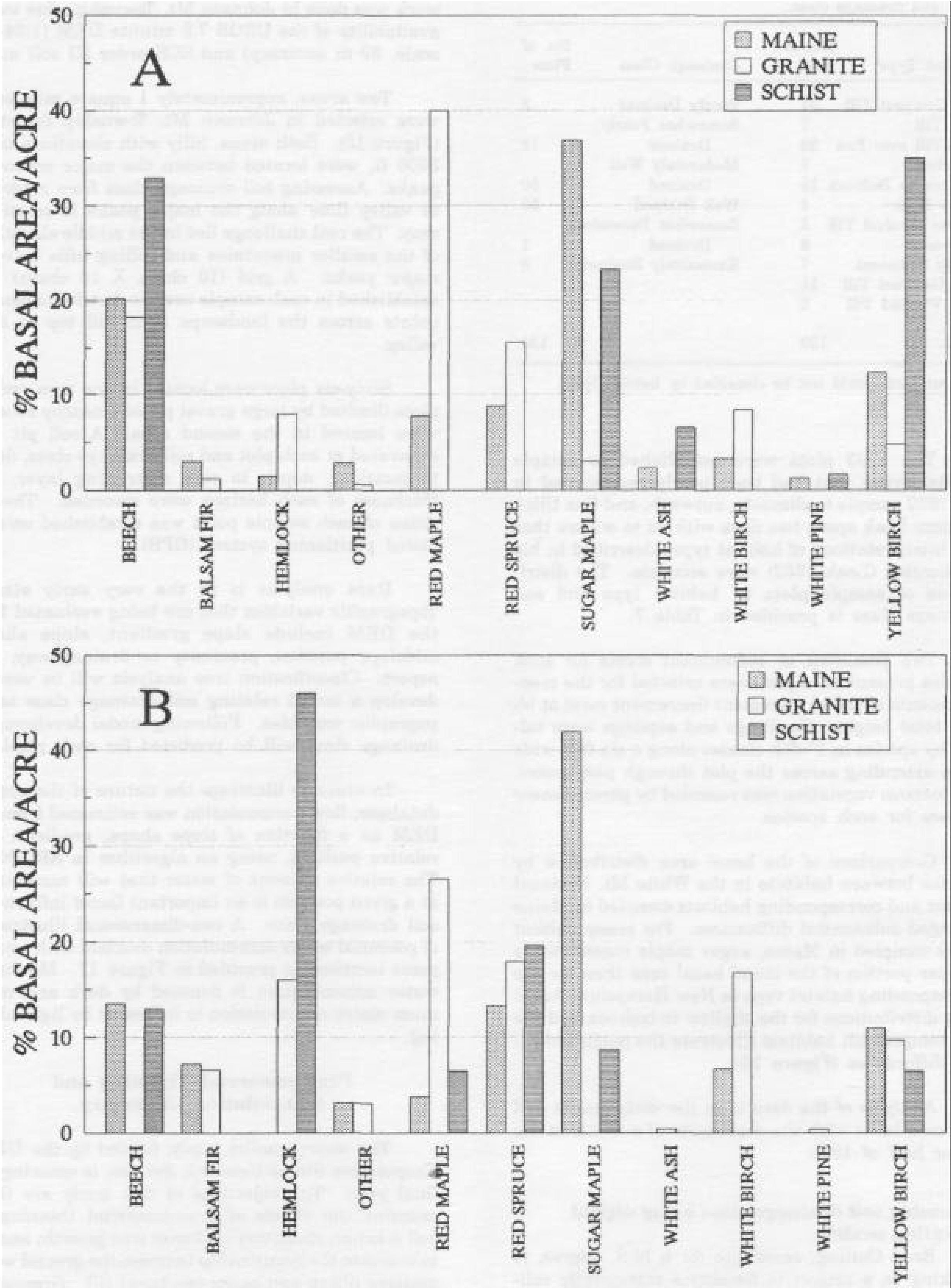

Figure 16. Comparison of basal area distribution by species for two habitat types ([a -top] dry compact till, and [b -bottom] shallow to bedrock) in Maine with those observed by Leak (personal communication) for New Hampshire on two different parent materials (granite and schist).

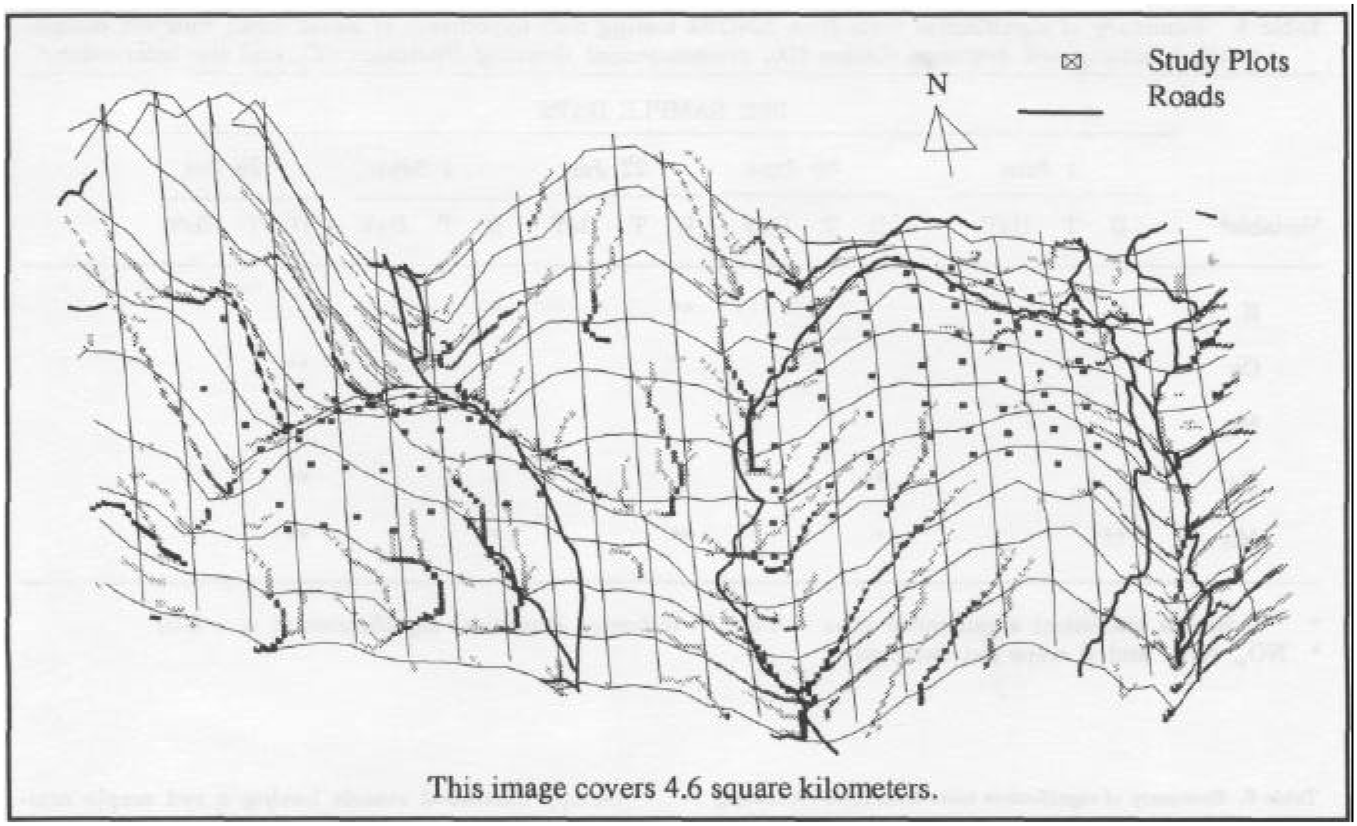

Figure 17. Location of sample points relative to the two-dimensional representation of the flow accumulation model. The most heavily shaded areas in this image represent regions of greatest flow accumulation.

Soil solution samples (25 and 50 cm below mineral surface) continue to be extracted (monthly except during periods of frozen conditions) using ceramic cup tension lysimeters on 27 plots (32.8 x 32.8 ft) distributed across the clearcut watershed. The current study consists of three treatments (control, PCT, PCT + fertilization) replicated 3, 4, and 2 times, on poorly drained (PD), somewhat poorly drained (SPD), and moderately well drained (MWD) soils, respectively. PCT treatments were applied in October 1991. One of the plots (plot 17) scheduled for PCT was not treated until May 1993. That plot was handled as a control in the statistical analyses for the first year following PCT. Analysis of variance was used to test null hypotheses of no effects of soil drainage class, PCT, and their interaction, on soil solution nutrient concentrations.

Fertilization treatments (ammonium nitrate in split applications each at 100 kg N/ha) were applied on 19 May and 7 July 1993. Plot 17 was thinned at the time of the first fertilizer application. Analysis of variance was used to test null hypotheses of equal mean soil solution nutrient concentrations by soil drainage class, treatment (PCT, fertilization), and the interaction of treatment and drainage class.

Precommercial thinning had no effect on nutrient concentrations of root zone soil solutions (25 cm below soil surface) during the first growing season following treatment (Table 8). Nitrate and ammonium were not even detected in the samples. Several nutrients differed by soil drainage class. There was no interaction between PCT and soil drainage class. Concentrations of Na and Mn were generally greater on poorly drained soils whereas K concentrations were higher on moderately well drained soils.

Treatment had a significant effect on all nutrients (with the exception of ammonium) in the 25 cm soil solution in the first sampling following fertilization application, completely overshadowing the effects of soil drainage class (Table 9). Mean separation clearly identified the impacts of fertilization. The effects of drainage class began to reappear by the second month after treatment. In addition, the interaction between soil drainage class and treatment was significant for K, Ca, and Mg. These results were presented at the Soil Science Society of America annual meeting in November, at Cincinnati, OH.

Analysis of the soil solution chemistry data is continuing. Data from the August sampling should reflect the impacts of the second application of the split fertilizer treatment. Tree growth response will be analyzed during the winter months.

Table 8. Summary of significance tests from ANOVA testing null hypotheses of equal mean nutrient concentrations, among soil drainage classes (D), precommercial thinning treatment (T), and the interaction.'

	1992 SAMPLE DATE														
	4 June			30 June			22 July			4 Sept.			28 Oct		
Variable[1]-	D	T	DxT	D	T	DxT	D	T	DxT	D	T	DxT	D	T	DxT
K	*						**			*					
Ca												**			
Mg										*					
Na				**			*				*			**	
Mn	**			*			**				*			**	

* indicates statistical significance at a = 0.05; ** indicates statistical significance at *a* = 0.01. [b]
NO_3, NH_4, and P were not detected.

Table 9. Summary of significance tests from ANOVA testing null hypotheses of equal mean nutrient concentrations among PCT and fertilization treatments (T) soil drainage classes (D) and their interaction for 1993'.

	Sample Date					
	30 June			7 July		
Nutrient	D	T	D*T	D*T		
NO,						
NH_4					**	
K		**		*	**	*
Ca		*		*	*	*
Mg		*		*	**	*
Mn		**		**	**	
Na		«*			*	

• + indicates statistical significance at a = 0.10;
* indicates statistical significance at a = 0.05;
** indicates statistical significance at a = 0.01.

Verification of Climatic Zones

As part of a joint venture with Dr. Ivan Fernandez to evaluate the relationship between rates of nutrient cycling and climatic variables, four transects were established across the climatic gradient identified by Briggs and Lemin (1992) (Figure 15). Stand criteria for plot location were closed canopy hardwood stands having a red maple component growing on well and moderately well drained glacial till soils. Red maple was chosen because it is present throughout the entire state.

Air and soil temperature has been monitored at the transect ends using continuously recording data loggers. In spite of recurring problems with instrumentation, we are beginning to compile a fairly complete record of daily temperature fluctuations across the state in closed canopy northern hardwood stands. These differences are illustrated for the eight plots in the gradient study along with data for the Weymouth Point clearcut watershed for a day selected from each of four seasons (Figure 18).

A cursory look at the data indicates that we were generally successful in locating plots to cover the climatic gradient in Maine. However, the ranking of sites by energy input requires more than just a cursory examination of daily temperature patterns. Although there are trends (Portage Lake west is usually the coldest site) there are also ocassional irregularities (Portage Lake east was coldest on July 14). Heat sum accumulations, summation of daily temperature integrals over time, will be computed. It is interesting to note the wider range between high and low temperatures in the clearcut at Weymouth Point relative to the those under closed canopy northern hardwoods.

Variation in the temperatures of forest floor was less than that of air temperature (Figure 19). Temperature of the soil at 25-cm depth did not vary on a daily basis.

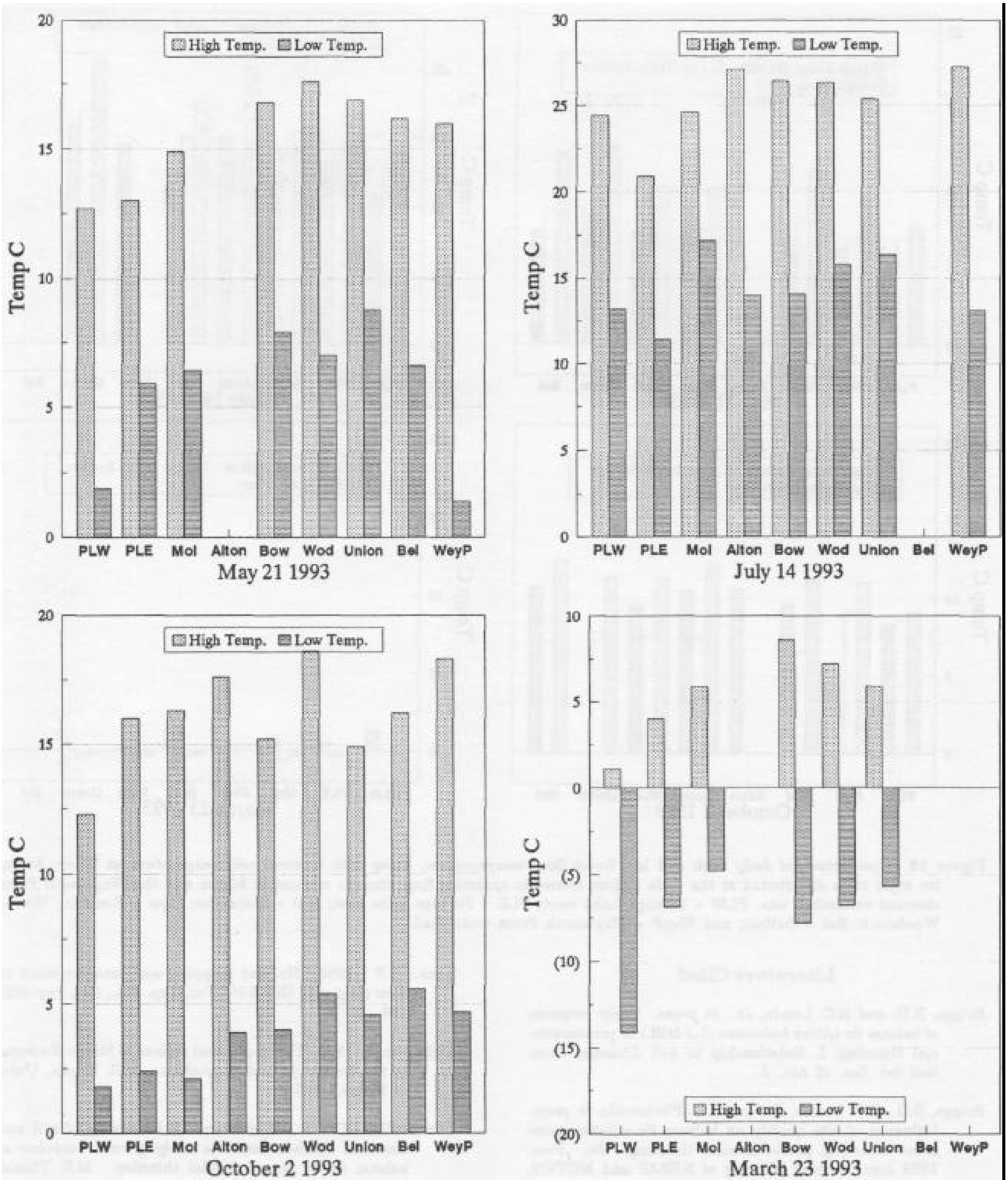

Figure 18. Comparison of daily high and low air temperatures for eight sites distributed at the ends of four transects spanning four climatic regions in Maine and the Weymouth Point clearcut watershed site. PLW = Portage Lake west; PLE = Portage Lake east; Mol = Molunkus; Bow = Bowdoin; Wod = Woodstock; Bel = Belfast; and WeyP = Weymouth Point watershed. Note change in scale among dates.

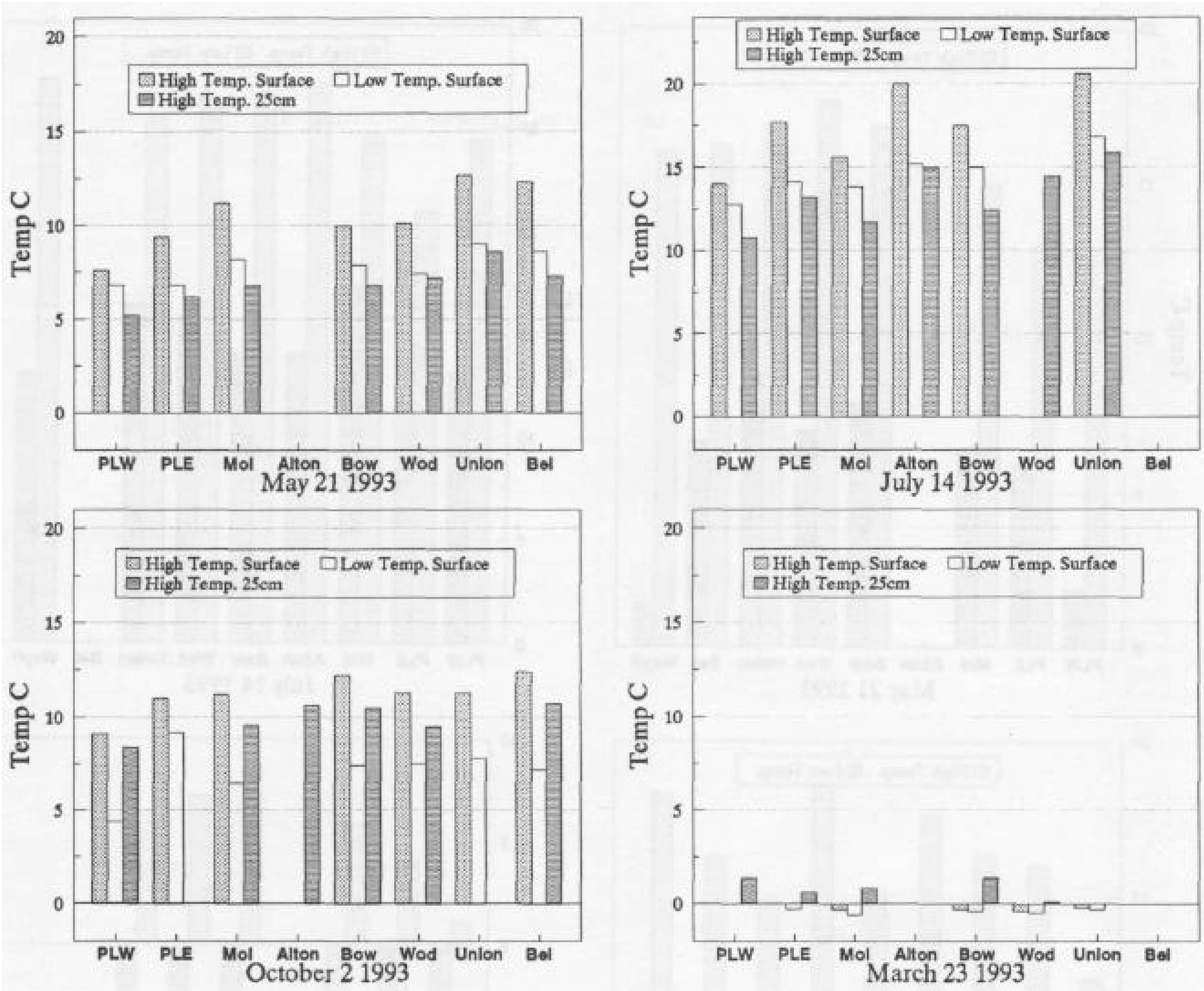

Figure 19. Comparison of daily high and low forest floor temperatures, along with mineral soil temperature at 25-cm depth, for eight sites distributed at the ends of four transects spanning four climatic regions in Maine and the Weymouth Point clearcut watershed site. PLW = Portage Lake west; PLE = Portage Lake east; Mol = Molunkus; Bow = Bowdoin; Wod = Woodstock; Bel = Belfast; and WeyP = Weymouth Point watershed.

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TREE IMPROVEMENT

Dr. Michael S. Greenwood and Hugo Volkaert

Second-year height measurements on the intra- and inter-specific hybrid larch study at Johnson Mountain were completed in October 1993. As reported last year, this test was established in May 1992, and survival and second-year growth have been quite good despite some browsing. This test is unique in comparison with the larch seed source trials at Unity and Milo, in that full-sib crosses from selected parents of tamarack, Japanese and European larch have been planted. The parents were selected on the basis of good growth performance in Maine (tamarack and Japanese larch) or in the Lake States (European larch). Genetic variation within full-sib families should be much less than within open-pollinated, half-sib families, but variation between full-sib families is potentially greater. One approach to attainment of maximum genetic gain requires the evaluation and eventual deployment of full-sib families, which can be done via seed or rooted cuttings.

The Johnson Mountain test consists of both inter- and intra-specific hybrids between Japanese, European, and Eastern larch (tamarack), plus check lots of European larch from Poland and von Lochow hybrid larch from Germany, which is used for some of Scott's operational larch plantations. Differences among individual crosses were highly significant ($p < 0.0001$), using the plot x cross interaction as the error term, since the latter was significant ($p < 0.0001$), as was variation among plots. Significant variation among plots is to be expected because genotype by environment interactions are likely in full-sib family tests.

Differences among overall means for all the groups of crosses made were also highly significant ($p < 0.0001$) and are shown in Table 10. Although Tarn x Jap crosses were very difficult to make (because of low seed set), we were able to establish 47 plants by pooling the few seed available from a number of attempted crosses on two female parents. As a group, they are significantly better than all the other groups and crosses. The next best group of crosses overall was the Tarn x Euro hybrids, based on 5 crosses consisting of a total of 189 trees, followed by the Jap x Euro and Euro x Jap crosses, which were virtually identical. The single best cross in the test was a Euro x Jap hybrid (represented by 29 plants), with a mean height of 113 cm. The intra-specific crosses all rank below the hybrids. The Jap x Jap crosses suffered some frost damage to their leaders. Two check lots, a Polish-European seed source (represented by 25 trees) and the von Lochow Jap x Euro hybrid (represented by 27 trees), are included for comparison. Surprisingly, the von Lochow hybrid ranked as one of the worst families in the test, while the Polish-European source ranked slightly below average. We cannot conclude that the von Lochow hybrid is as bad as it appears since it is only represented by 27 trees, and by chance some trees may have been in poor locations. The survival for this seed lot was 90%, right on the average for the test. Furthermore, some family rank changes are likely over the next several years.

Although only tentative conclusions can be drawn based on two years of height growth, the performance of both the Tarn x Jap and Tarn x Euro hybrids is cause for cautious excitement if they maintain their rankings in the future. In other larch tests, tamarack may start out well, but is later overtaken by European and Japanese larch and their hybrids. However, if the results presented here hold up, the Tarn x Jap crosses could be mass produced as rooted cuttings, while the Tarn x Euro cross can be made using tamarack as the female parent. In conclusion, there seems little doubt that other hybrids besides Jap x Euro are showing hybrid vigor, and that there is considerable variation among larch hybrid families. Further testing of hybrid families made from parents already adapted to conditions in Maine should result in considerable improvement over the already excellent performance of larch in Scott's operational plantations.

Table 10. Percentage survival and height growth for groups of intra- and inter-specific crosses after two years for Johnson Mountain Hybrid Larch Test. Different letters after height indicate means are different at $p < 0.05$ (Duncan's test).

Cross	# Crosses	# Trees	% Survival	Ht (cm.)
Tarn x Jap	2	47	85	107 a
Tarn x Euro	5	189	91	96 ab
Jap x Euro	9	196	84	93 ab
Euro x Jap	8	220	87	93 ab
Tarn x Tarn	8	258	96	89 be
Jap x Jap	6	174	83	81 be
Euro x Euro	7	196	93	79 d
<u>Checks</u>				
Euro (Polish)		25	86	86
JxE (von Lochow)		27	90	66

TREE IMPROVEMENT

Dr. Katherine K. Carter

The application of tree improvement programs implies that the resulting genetically improved stock will be deployed through operational planting programs. One of the key factors involved in the successful establishment of planted seedlings is believed to be their ability to generate new roots quickly after planting, which allows them to capture needed water and nutrients for rapid growth. Thus, it is reasonable to ask whether this ability to establish new roots may itself be a genetically variable factor. To investigate this question, graduate student Yuguo Huang examined the influence of genetic variability on root growth and its relationship to first-year growth of Japanese larch.

Fifteen open-pollinated families of Japanese larch were grown in the greenhouse in Leach tube containers and overwintered outdoors in a shadehouse. The following spring, 15 seedlings from each family were brought into the greenhouse for a three-week root growth test period. The following root growth parameters were measured at the end of the 3-week period: number of new roots outside the container rootball (NRORB), length of new first-order lateral roots (NFOLR), new root dry weight (NRDWT), and number of first-order lateral new roots (NEW1°L). A second group of 15 seedlings/family were stressed by exposure to 40°C for 5 hours, prior to the beginning of RGP tests. At the same time, twenty seedlings of each family were planted in an outdoor nursery bed to simulate transplanting to the field, and their survival and growth were measured at the end of the first and second growing seasons. In addition, family heritability (h^2) values were calculated for the root growth traits.

All of the root growth traits showed large and statistically significant differences among the families of Japanese larch, and family heritability values were high (Table 11). These figures indicate that there are large genetic influences on the ability of Japanese larch to rapidly generate new roots at the time of transplanting.

Table 11. Heritabilities and range of family mean values, for four root growth traits in Japanese larch.

	NRORB (#)	LFOLR (cm)	NRDWT (mg)	NEW 1°L (#)
h^2	0.75	0.74	0.94	0.31
range	17-40	9-27	9-35	2-9

After one growing season in the nursery bed, the seedlings averaged 31 cm tall (family range 17-44 cm), and this increased to 62 cm (family range 44-76) after the second growing season. Most root growth traits were significantly correlated with first-year seedling survival and growth (Table 12). Heat stress prior to RGP testing improved the observed first-year correlation with field tests (Table 13). Correlations were generally lower during the second year, except for stressed seedling RGP correlations with 2-year height, which remained high. The decrease in 2nd-year correlations for the unstressed seedlings probably indicates that after the initial establishment period, other genetically variable factors besides root growth traits were making larger contributions to the overall seedling growth. However, root growth ability is an important factor to consider during the initial establishment phase of plantations. Since all root growth traits show similar correlations with first-year growth, we recommend that NRORB be used for quick estimates of root growth potential, since it is the easiest and quickest of these traits to measure.

Table 12. Correlation coefficients between root regeneration measures (unstressed seedlings) and seedling height and survival after one and two growing seasons.

	NRORB	LFOLR	NRDWT	NEW 1°L
1" year height	0 59'.	0 75"	0 ,47'	0.46
1" year survival	0 49'	0 ,47*	0 ,31	0.25
2nd year height	0 61*	0 63'	0 ,41	0.22
2" year survival	0 30	0 .13	0 ,23	0.23

* $p < 0.05$ ** $p < 0.01$

Table 13. Correlation coefficients between root regeneration measures (stressed seedlings) and seedling height and survival after one and two growing seasons.

	NRORB	LFOLR	NRDWT	NEW 1°L
1*' year height	0.76"	0.77"	0.87"	0.65*
1*' year survival	0.68"	0.59'	0.65'	0.66"
2nd year height	0.76"	0.78"	0.87"	0.69"
2nd year survival	0.37	0.29	0.43	0.48'

* $p < 0.05$ ** $p < 0.01$

GROWTH AND YIELD

Dr. Robert S. Seymour

Growth and Yield Prediction of Managed Northern Conifer Forests

Important progress was made in reformulating the TASS model (obtained from the B. C. Ministry of Forests in 1991) for Maine conifer species. Dan Gilmore, Ph.D. student, completed the second and final year of intensive field sampling. Detailed stem analysis data were collected from 10 balsam fir trees from each of 4 canopy positions or crown classes (Table 14) after stem elongation and primary growth had ceased during the late summer months of 1992 and 1993. This gives a total data base of 51 trees, including those sampled in 1992. Very detailed crown and stem analyses were completed, and laboratory analyses of radial growth, sapwood area, foliar biomass, and crown architecture are being carried out. Radial increment and sapwood data will be used to compare the stem form development and vertical distribution of sapwood of balsam fir among crown classes. Crown measurement data will be used to construct a model to describe crown shape, and the equations incorporated into TASS. Data obtained from branches dissected for detailed analyses will be used to construct a model to predict the needle mass of individual branches. Specific leaf area will be used to convert total foliage biomass to total projected foliage area for each tree. A model will then be constructed to predict projected leaf area from sapwood area. Equations to predict stemwood increment from crown parameters will then be formulated and used to create a version of TASS that will "grow" managed balsam fir stands.

A comprehensive summary of production silvicultural systems for the Northeast was completed and presented at the 1992 National SAF Convention in Richmond, Virginia (Seymour 1992). Silvicultural systems and stocking guidelines for producing high-value hardwood and white pine stands using a crop-tree approach are reviewed. Yields resulting from conifer plantation silviculture throughout the Northeast and Maritime Provinces are also summarized and compared to empirical yields of natural stands. Results show that well-managed Norway spruce, red pine, and exotic larch plantations yield three to five times as much merchantable wood as unmanaged stands (Figure 20).

Table 14. Mensurational characteristics of sample trees by canopy position.

Crown class	n	DBH" (cm)	Height" (m)
suppressed	10	6.2 (2.5-10.2)	6.1 (4.0-12.8)
intermediate	10	10.8 (5.3-14.5)	12.7 (7.2-16.0)
codominant	10	20.2 (9.5-29.7)	16.7 (7.6-19.6)
open-grown	10	14.0 (5.7-30.5)	9.6 (4.4-16.6)

" range of data in parenthesis

In a subsequent paper presented at the New England SAF Meeting in Portland (Seymour 1993), plantation silviculture was compared to systems based on natural regeneration, including the effects of extended shelterwood management vs. clearcutting, with and without spacing and herbicide release. When all systems are compared in terms of total wood cost (roadside, including harvesting), plantations on high sites proved to be the least expensive way to produce industrial fiber (Figure 21). Plantations compare favorably to precommercial thinning of natural stands for several reasons. First, plantation yields are higher because of better site quality and full stocking early in the rotation (Figure 22). Densely regenerated, natural stands suitable for precommercial thinning are most often found on less productive sites of impeded drainage where hardwood competition is not as severe. Furthermore, disturbance from the final overstory removal harvest reduces stocking of natural stands to 80% or less depending on the spacing of skid trails. Secondly, planting on a relatively wide spacing (e.g., 10 by 10 feet) without site preparation actually costs much less (about $110 per acre at $0.25 per tree) than precommercial thinning a dense natural stand ($150-200+ per acre).

Silvicultural systems for natural spruce-fir stands depend on the stand origin. The best option is to grow the regeneration to sapling size (5-10 years beyond breast height) beneath a partial overstory -- the "extended" shelterwood system. This usually avoids herbicide release and increases future mean annual yields by shortening the effective rotation. Developing saplings differentiate better in height beneath the overstory, reducing the need for costly precommercial thinning. If the stands originate from small advance seedlings after a clearcut harvest, herbicide release is needed, but is clearly justified economically in order to maintain high stocking and avoid conversion to hardwoods. Under either system, instead of thinning precommercially, it may be better to plan an early commercial thinning at ages 25-40 using a small cut-to-length processor-forwarder logging system. Such thinnings will be costly due to the small tree size (3-6" dbh) removed, but will produce substantial volumes of fiber and allow future crop trees to be selected. Precommercial thinnings will definitely shorten the time to reach merchantable size and may be justified on the grounds of ensuring a strategic future wood supply. However, the wood will be very costly.

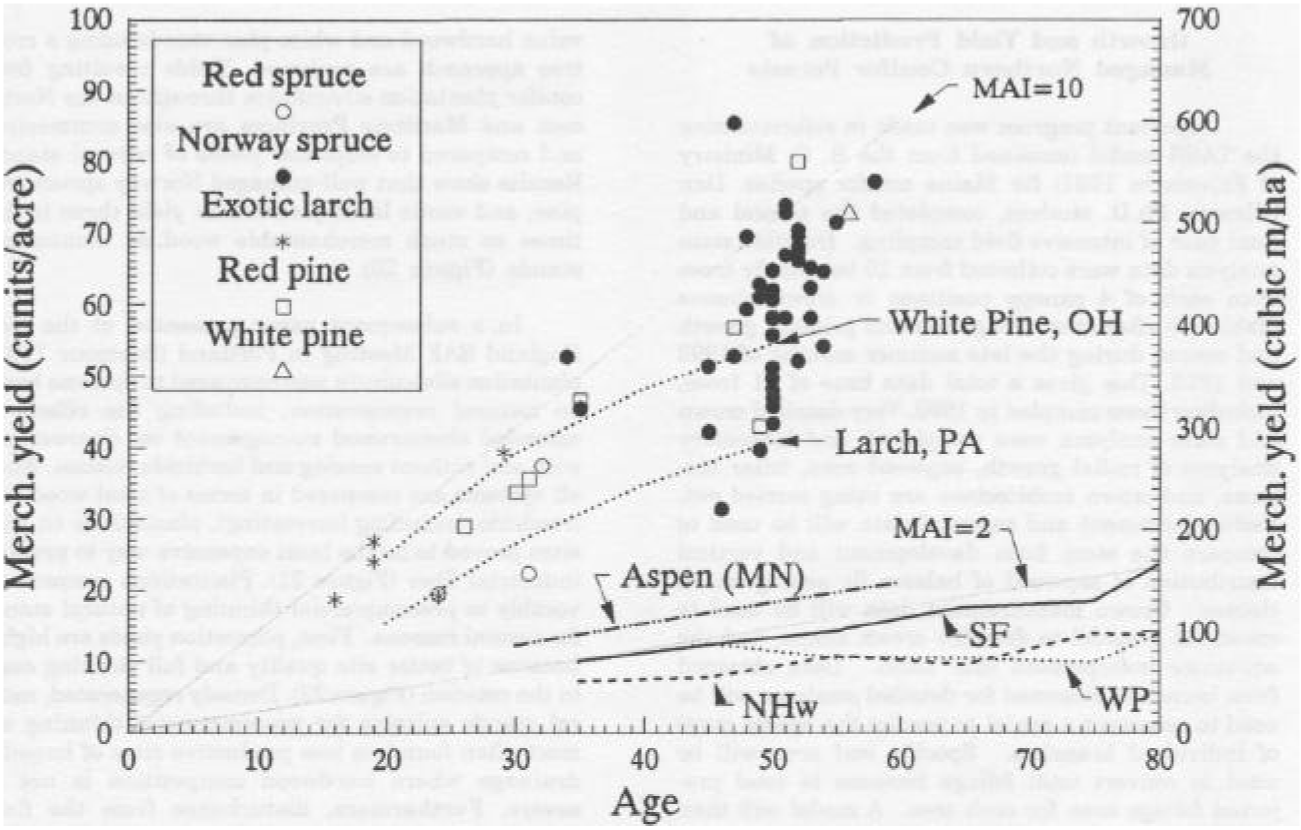

Figure 20. Selected yields of conifer plantations in northeastern North America compared with empirical yields of common species groups (SF = spruce-fir in SF type; NHw = northern hardwoods in NHw type; WP = white pine in WP type) in Maine and aspen in Minnesota. Individual plantation yields are shown as points; yield studies are shown as dotted lines. Mean annual increments (MAI) of 2 and 10 m^3*fhafyeai* are shown for reference, (see Seymour [1992] for detailed description of data sources)

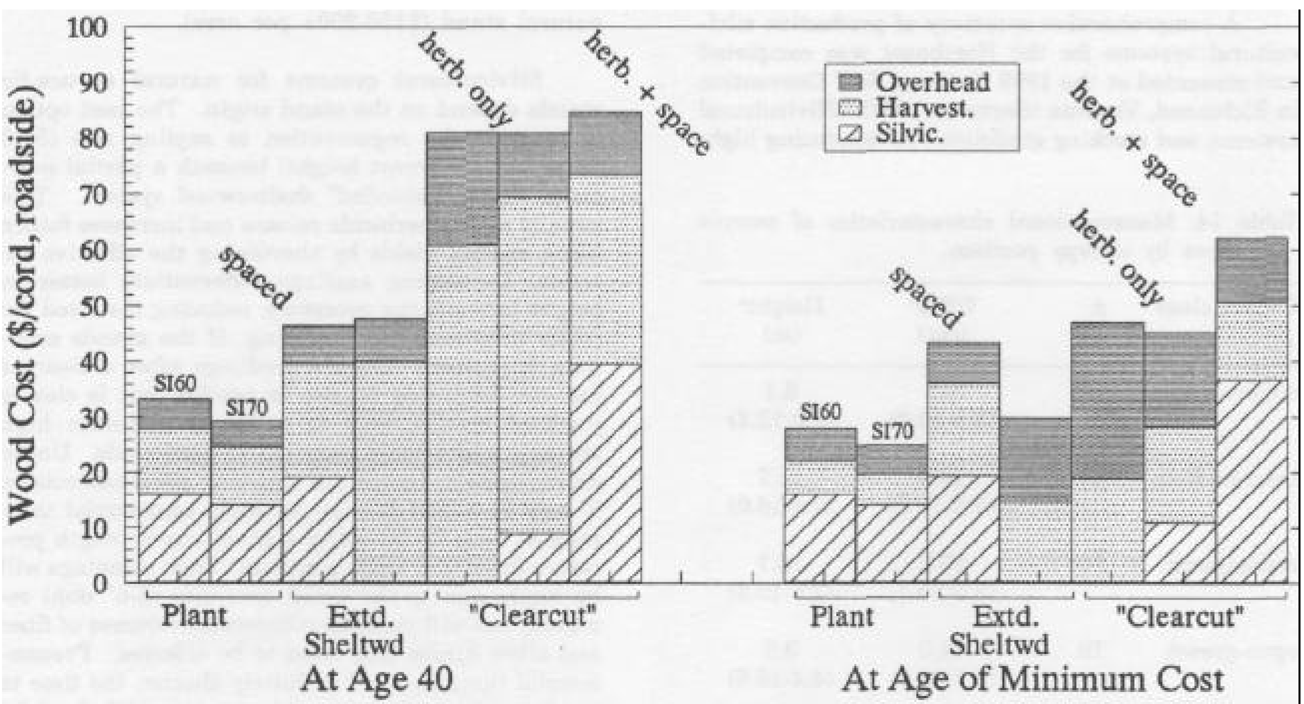

Figure 21. Total wood costs for the seven systems analyzed, at rotation ages of 40 and at the age of minimum cost for each system.

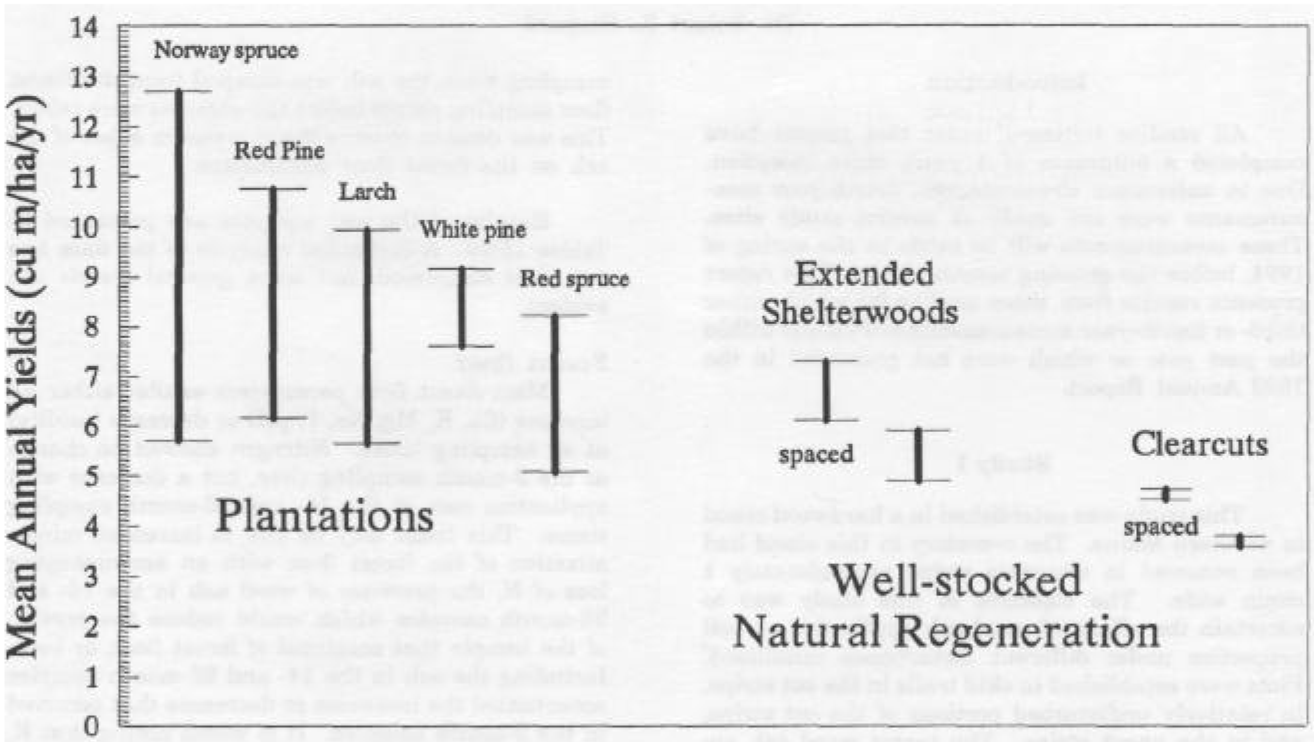

Figure 22. Comparison of plantation yields by species (from Seymour 1992) with naturally regenerated stands of differing origin, with and without spacing.

Stand Development

An analysis of drainage-induced vegetation differences in herbicide-released stands (based on the work of former Ph.D. student Xiandong Meng) was completed and is currently in review by the Canadian Journal of Forest Research. Former Ph.D. student Mary Ann Fajvan's analysis of stand development and canopy stratification patterns of uneven-aged white pine-hemlock--red spruce stands in eastern Maine was published (Fajvan and Seymour 1993). Two other publications of her research on the subjects of site index prediction and productivity of these mixed-species stands are under revision.

Review Articles

The widely used textbook and reference *Regional Silviculture of the United States* was extensively revised as a third edition during 1993.1 rewrote completely Chapter 2 (The Northeast), which provides a thorough treatment of the spruce-fir and northern hardwood forest types, along with shorter coverage of the variants of the oak and white pine types occurring in the Northeast. More than 110 new references published since the previous edition in 1980 were added. This book will appear early in 1994; draft copies of the Northeast Chapter are available to CFRU Cooperators by request.

An article discussing the evolution of silvicultural practice in the United States (O'Hara et al. *in press)* was accepted by the Journal of Forestry for the December 1993 issue. The main theme of this paper is how innovative changes in silvicultural systems can be used to overcome problems with historical practices and meet the broad mandate for ecosystem management on the nation's forests.

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SLUDGE AND ASH

Dr. Robert K. Shepard

Introduction

All studies initiated under this project have completed a minimum of 4 years since inception. Due to unforeseen circumstances, fourth-year measurements were not made at several study sites. These measurements will be made in the spring of 1994, before the growing season starts. This report presents results from three studies for which either third- or fourth-year measurements were made within the past year or which were not presented in the 1992 Annual Report.

Study 1

This study was established in a hardwood stand in northern Maine. The overstory in this stand had been removed in alternate strips approximately 1 chain wide. The objective of this study was to ascertain the effects of wood ash application on soil properties under different disturbance conditions. Plots were established in skid trails in the cut strips, in relatively undisturbed portions of the cut strips, and in the uncut strips. The target wood ash application rates were 0, 3, 6, and 9 tons of calcium carbonate equivalent per acre. Actual rates were 0, 2.7, 5.4, and 8.1 tons of calcium carbonate equivalent per acre. Each application rate was replicated three times in each of the disturbance conditions. Soil and forest floor samples were taken 2, 14, and 26 months after the plots were treated. At the two-month sampling time, the ash was scraped from the forest floor sampling points before the samples were taken. This was done to observe the short-term effect of the ash on the forest floor parameters.

Results of the soil analyses are presented in Tables 15-20. A statistical analysis of the data has not been completed, but some general trends are evident.

Forest floor

Most forest floor parameters exhibit either an increase (Ca, K, Mg, Na, P, pH) or decrease (acidity) at all sampling times. Nitrogen showed no change at the 2-month sampling time, but a decrease with application rate at the 14- and 26-month sampling times. This trend may be due to increased mineralization of the forest floor with an accompanying loss of N, the presence of wood ash in the 14- and 26-month samples which would reduce the portion of the sample that consisted of forest floor, or both. Including the ash in the 14- and 26-month samples accentuated the increases or decreases that occurred in the 2-month samples. It is worth noting that K, which is quite mobile, showed much smaller concentrations in the 14- and 26-month samples, even though those samples contained ash. The large increases in pH have implications for nutrient availability and for the nature of the microflora and fauna in the forest floor.

Table 15. Forest floor characteristics two months after application of wood ash.

Treatment	Application Rate[1]	Parameter									
		TKN (mg/kg)	Ca (meq/100g)	K (meq/100g)	Mg (meq/100g)	Na (meq/100g)	P (mg/kg)	pH	Acidity (meq/100g)	Cd (mg/kg)	Pb (mg/kg)
Cut Strip											
	0	15000	11.2	1.7	2.4	.16	144	4.3	9.5	.72	66
	2.7	15700	21.1	3.8	4.9	.29	193	4.8	8.0		
	5.4	16700	26.8	5.3	6.9	.42	288	5.0	8.9		
	8.1	17700	39.1	9.6	10.2	.62	296	5.7	8.3	1.17	42
Uncut Strip											
	0	19300	18.7	1.6	3.4	.19	277	4.5	11.7	.63	54
	2.7	14300	43.8	5.9	6.9	.37	372	5.8	8.9		
	5.4	16300	53.2	7.2	12.6	.44	391	6.5	9.3		
	8.1	14000	56.4	10.0	11.2	.59	412	6.7	9.7	1.57	63
Average											
	0	17200	15.0	1.6	2.9	.17	210	4.4	10.6	.68	60
	2.7	15000	32.5	4.9	5.9	.33	283	5.3	8.5		
	5.4	16500	40.0	6.2	9.7	.43	340	5.8	9.1		
	8.1	15834	47.8	9.8	10.7	.60	354	6.2	9.0	1.37	53

[1] Tons $CaCO_3$ equivalent per acre.

Table 16. Forest floor characteristics 14 months after application of wood ash.

Treat-ment	Appli-cation Rate[1]	TKN (mg/kg)	Ca (meq/lOOg)	K	Mg	Na	P (mg/kg)	pH	Acidity (meq/lOOg)
Cut									
	0	13700	11.8	1.3	2.2	.08	136	4.2	7.2
	2.7	12500	133.7	1.5	11.5	.20	597	6.7	1.6
	5.4	12400	164.3	1.6	14.6	.30	658	6.8	1.6
	8.1	9400	254.0	1.5	18.6	.41	777	7.3	1.3
Uncut Strip									
	0	15100	9.9	1.9	2.5	.10	219	4.2	7.6
	2.7	12700	91.8	2.0	10.6	.18	509	6.6	1.6
	5.4	13200	144.3	2.5	15.7	.31	750	6.8	1.6
	8.1	10300	276.0	2.4	19.9	.44	976	7.2	1.3
Average									
	0	14400	10.9	1.6	2.4	.09	178	4.2	7.4
	2.7	12600	112.8	1.7	11.5	.19	553	6.6	1.6
	5.4	12817	154.3	2.0	15.2	.31	704	6.8	1.6
	8.1	9833	265.0	1.9	19.3	.43	870	7.3	1.3

Tons $CaCO_3$ equivalent per acre.

Table 17. Forest floor characteristics 26 months after application of wood ash.

Appli-Treat-cation ment	Rate[1]	TKN (mg/kg)	Ca (meq/lOOg)	K	Mg	Na	P (mg/kg)	PH	Acidity (meq/lOOg)
Cut									
	0	15700	12.6	1.5	2.3	.20	177	4.2	6.9
	2.7	11100	90.9	2.2	9.0	.30	523	6.8	1.3
	5.4	9300	206.5	2.4	14.4	.43	812	7.1	1.5
	8.1	9800	258.4	2.8	15.8	.47	905	7.2	1.5
Uncut Strip									
	0	12400	7.5	1.2	1.6	.20	154	4.2	6.7
	2.7	12200	123.1	2.7	10.4	.33	735	6.6	1.8
	5.4	10500	194.8	2.9	14.6	.40	906	6.9	1.7
	8.1	10900	201.2	2.9	13.3	.40	843	7.0	1.7
Average									
	0	14000	10.1	1.4	2.0	.20	166	4.2	6.8
	2.7	11600	107.0	2.5	9.7	.32	629	6.7	1.6
	5.4	10000	200.7	2.6	14.5	.42	859	7.0	1.6
	8.1	10300	229.8	2.9	14.5	.44	874	7.1	1.6

Tons $CaCO_3$ equivalent per acre.

Mineral soil

The effect of the wood ash was pronounced after only 2 months. The trends observed were much the same as for the forest floor, except that the values of the individual parameters were generally lower. There was much less of an effect of the ash on pH and acidity. As with Cd in the forest floor, there was a small increase in Cd in the mineral soil due to the ash application. The concentration of Pb was not affected. There are no evident differences between disturbance categories for any of the parameters.

Table 18. Mineral soil characteristics two months after application of wood ash.

Treat-ment	Appli-cation Rate[1]	Parameter									
		TKN (mg/kg)	Ca (meq/lOOg)	K	Mg	Na	P (mg/kg)	PH	Acidity (meq/lOOg)	Cd (mg/kg)	Pb (mg/kg)
Skid Trail											
	0	2100	.21	.07	.08	.02	10.1	4.4	10.0	0.50	10.0
	2.7	1660	.49	.09	.16	.04	9.0	4.4	9.1		
	5.4	1470	.65	.44	.18	.06	6.5	4.6	8.1		
	8.1	1700	1.21	1.46	.43	.07	6.2	4.7	6.8	2.20	10.0
Cut Strip											
	0	2130	.32	.06	.14	.02	9.9	4.1	11.3	.67	8.3
	2.7	2000	.37	.19	.13	.05	11.0	4.2	12.5		
	5.4	2030	.29	.13	.17	.05	10.6	4.2	8.5		
	8.1	1770	.96	.39	.19	.09	8.2	4.3	7.8	.67	10.0
Uncut Strip											
	0	2230	.38	.05	.10	.03	8.9	4.2	11.1	.83	8.3
	2.7	1930	.35	.13	.12	.05	10.6	4.2	11.5		
	5.4	2070	.49	.52	.16	.08	8.8	4.3	9.9		
	8.1	2400	.81	1.16	.15	.15	10.3	4.2	9.2	2.17	8.3
Average											
	0	2160	.30	.06	.10	.03	9.6	4.2	10.8	.67	8.9
	2.7	1870	.40	.138	.14	.05	10.2	4.3	11.0		
	5.4	1860	.48	.364	.17	.07	8.6	4.4	8.8		
	8.1	1960	.99	1.01	.26	.10	8.2	4.4	7.9	1.68	9.4

Tons $CaCO_3$ equivalent per acre.

Table 19. Mineral soil characteristics 14 months after application of wood ash.

Treat-ment	Appli-cation Rate[1]	Parameter									
		TKN (mg/kg)	Ca (meq/lOOg)	K	Mg	Na	P (mg/kg)	pH	Acidity (meq/lOOg)	Cd (mg/kg)	Pb (mg/kg)
Skid Trail											
	0	2200	.53	.07	.15	.02	10.5	4.6	6.1	.31	14.0
	2.7	2000	1.00	.29	.25	.02	7.9	4.7	5.2		
	5.4	1870	.96	.40	.27	.03	11.6	4.7	4.9		
	8.1	2030	1.45	1.05	.73	.04	7.8	5.0	3.7	.39	12.0
Cut Strip											
	0	2270	.59	.09	.20	.03	10.5	4.4	9.5	.25	15.0
	2.7	2100	.62	.20	.25	.03	6.9	4.4	8.6		
	5.4	2170	.87	.28	.36	.03	8.5	4.5	6.7		
	8.1	2400	2.42	.79	.90	.05	9.1	5.0	4.2	.33	15.0
Uncut Strip											
	0	2270	.51	.07	.17	.03	11.8	4.4	10.1	.26	15.0
	2.7	2330	.86	.14	.27	.03	9.5	4.5	7.7		
	5.4	2330	1.33	.27	.59	.04	10.8	4.6	7.4		
	8.1	2030	2.23	.49	.76	.05	12.1	4.7	5.7	.21	13.0
Average											
	0	2250	.54	.08	.17	.03	10.9	4.4	8.6	.27	15.0
	2.7	2140	.83	.21	.26	.03	8.1	4.6	7.2		
	5.4	2120	1.03	.32	.41	.03	10.3	4.6	6.3		
	8.1	2160	2.03	.77	.80	.05	9.7	4.9	4.5	.31	13.0

Tons $CaCO_3$ equivalent per acre.

Table 20. Mineral soil characteristics 26 months after application of wood ash.

Application Rate[1]	Treatment	TKN (mg/kg)	Ca (meq/100g)	K (meq/100g)	Mg (meq/100g)	Na (meq/100g)	P (mg/kg)	pH	Acidity (meq/100g)	Cd (mg/kg)	Pb (mg/kg)
Skid Trail											
0		2270	.54	.04	.12	.03	12.9	4.2	7.2	.24	5.7
2.7		1670	.90	.09	.20	.03	7.2	4.5	4.1		
5.4		2100	1.40	.20	.36	.03	13.3	4.4	5.0		
8.1		2130	1.73	.36	.64	.03	11.2	4.6	3.9	.21	6.0
Cut Strip											
0		2430	.54	.04	.15	.04	13.1	3.9	9.7	.16	7.3
2.7		2100	.82	.08	.27	.03	13.3	4.2	7.0		
5.4		2170	.94	.08	.34	.03	10.8	4.0	7.9		
8.1		2300	1.87	.10	.56	.04	12.5	4.4	5.4	.21	5.8
Uncut Strip											
0		2230	.44	.04	.12	.03	11.0	4.1	8.3	.18	6.0
2.7		2170	.58	.05	.19	.03	12.9	4.0	7.9		
5.4		2100	1.32	.11	.58	.03	12.7	4.2	7.5		
8.1		2470	1.50	.09	.41	.04	12.1	4.4	6.2	.23	6.9
Average											
0		2310	.51	.04	.13	.03	12.3	4.1	8.4	.19	6.3
2.7		1980	.77	.07	.22	.03	11.1	4.2	6.3		
5.4		2120	1.22	.13	.43	.03	12.3	4.2	6.8		
8.1		2300	1.70	.18	.54	.04	12.0	4.5	5.2	.22	6.2

[1] Tons $CaCO_3$ equivalent per acre.

Study 2

This study was established to determine the effects of a combination of papermill secondary sludge and wood ash on the growth of black spruce seedlings and on soil properties. The mixture was approximately 80% wood ash on a dry weight basis. It was applied at three different times (late May, late July, and late September) during the spreading season, at four rates (0, 2.4, 4.8, and 9.6 dry tons per acre), and for 1, 2, or 3 years in succession. Growth measurements were made prior to residual application and for the succeeding 4 years. Results of the fourth-year measurements are presented here.

Root collar diameter

Previous measurements of root collar diameter indicated significantly reduced growth as application rate increased. This reduction was attributed primarily to the stimulation of competing herbaceous vegetation by the sludge and ash mixture. The same phenomenon was observed in the fourth-year measurements (Figure 23). The control was significantly different from the other treatments, and the 2.4 and 9.6 tons per acre treatments were also significantly different. An overall trend of reduced root collar diameter with increasing application rate is evident in Figure 23. The maximum difference, which occurs between the control and the 9.6-tons-per-acre treatment, is only 0.28 inch.

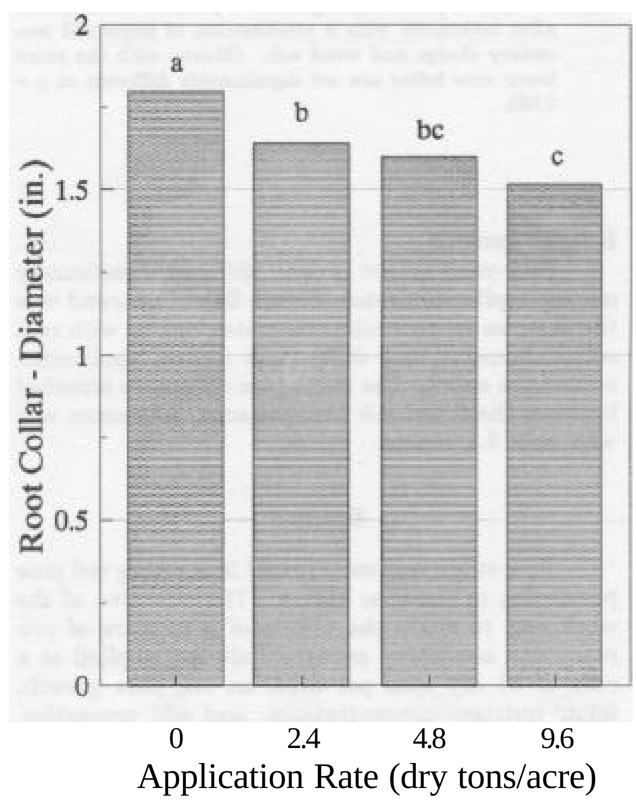

Figure 23. Root collar diameter of planted black spruce 4 years after treatment with a combination of papermill secondary sludge and wood ash (Means with the same lower case letter are not significantly different at p = 0.05).

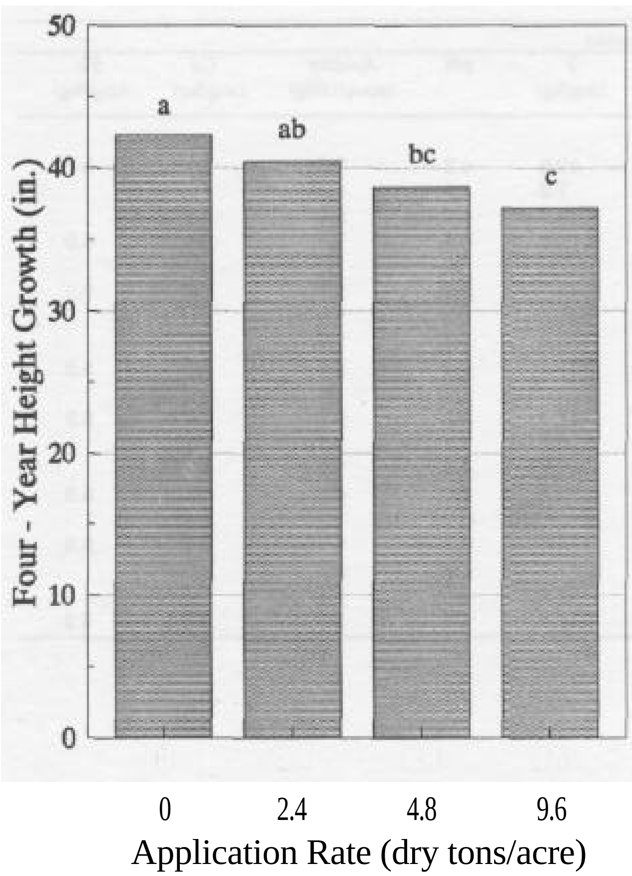

Figure 24. Four-year height growth of planted black spruce after treatment with a combination of papermill secondary sludge and wood ash. (Means with the same lower case letter are not significantly different at p = 0.05).

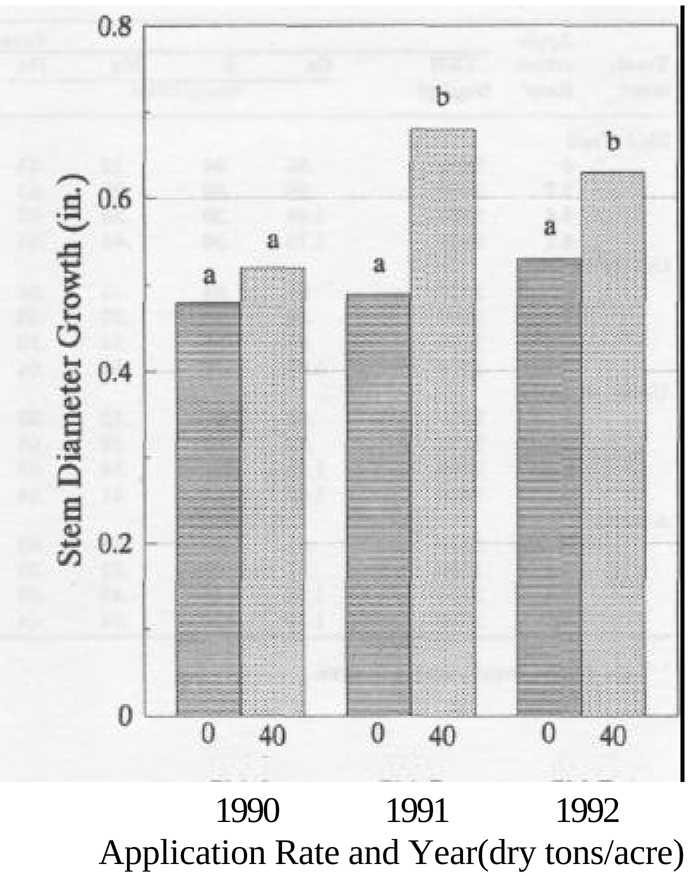

Figure 25. Stem diameter growth measured at 3 feet of planted red pine during the first 3 years after treatment with a combination of papermill primary and secondary sludge. Sludge was applied at rates of 0 *and* 40 dry tons per acre in October 1989. (Means with the same lower case letter are not significantly different at p = 0.05).

Height growth

Four-year height growth differed significantly among application rates (Figure 24). The trend was the same as for root collar diameter, and as with root collar diameter, the differences among application rates were small. The maximum difference occurred between the 0 and 9.6 tons-per-acre treatments and was only 5.1 inches.

Study 3

This study was established in a young red pine plantation in western Maine. The objective of the work was to study the effects of a mixture of primary and secondary papermill sludge, applied at a rate of 40 dry tons per acre, on red pine growth, foliar nutrient concentrations, and soil properties. This report describes stem diameter growth for the 3 years following treatment.

Diameter growth of trees in treated plots was significantly greater than diameter growth of the control during the second and third growing seasons after treatment (Figure 25). It appears, however, that the effect of the sludge will be relatively short-lived. Growth of treated trees was .20 inch greater than the control during the second growing season after treatment and 0.10 inch greater during the third growing season after treatment. Over the three growing seasons following treatment, treated trees outgrew the control by 0.34 inch.

HERBICIDE EFFECTS ON HABITAT AND NUTRITIONAL ECOLOGY OF MOOSE AND DEER IN MAINE

Dr. Frederick Servello, William Eschholz,
Kevin Raymond and Justin Vreeland

Introduction

The third and final year of field and laboratory work on this 3-year project was completed in 1993. William Eschholz (M.S. graduate student) will complete his thesis on the effects of glyphosate on moose activity and habitat in November 1993. Kevin Raymond (M.S. graduate student) will complete his thesis on the effects on moose nutrition in January 1994, and Justin Vreeland will complete his undergraduate honors thesis on the effects on food availability for white-tailed deer in December 1993. The results of these three projects ultimately will be combined into a single comprehensive report for CFRU.

Objectives

The objectives of the project are

1. to determine the effects of glyphosate on browse, energy, and protein availability for moose in winter, 1-2 and 7-10 years post-treatment;

2. to determine the effects of glyphosate on browse utilization and diet quality for moose, 1-2 and 7-10 years post-treatment;

3. to determine if intensity of stand use by moose differs between glyphosate-treated and untreated stands in winter;

4. to determine the effects of browse availability and stand characteristics (physical cover) on moose use of glyphosate-treated and untreated stands; and

5. to determine effects of glyphosate on food avail ability and quality for deer in summer, 2 and 7-10 years post-treatment.

Moose Habitat Use

As in 1992, moose activity was measured on a total of 31 clearcuts in winter 1993. Activity was measured 5 times on each site using transect surveys to count moose track aggregates, beds, and pellet groups. Track aggregates also were classified as foraging or non-foraging activity when possible.

At 1-2 years post-spray, the track counts of foraging moose and the number of beds were less (approximately 2x) in glyphosate-treated clearcuts than similarly aged untreated clearcuts. Counts of total moose track aggregates did not differ statistically, but tended to be greater in untreated clearcuts similar to foraging track aggregates. A reduction in moose foraging activity occurred in both the first and second winters after treatment despite our observation that the full effect of glyphosate on hardwood vegetation did not occur until the second winter post-spray. There was only 24% mortality for hardwood stems in the first winter post-spray (although most appeared physiologically stressed), compared to 73% by the second winter. Overall, it appeared that glyphosate treatment reduced moose activity in clearcuts during the first 2 years post-treatment, and the reduction in activity was likely caused by a reduction in browse (hardwood species) availability.

Based on 2 years of data, track counts of foraging moose and the number of beds were greater on glyphosate-treated clearcuts at 7-10 years post-spray than on untreated sites. Counts of total track aggregates did not differ. The high density of relatively large conifers on these older treated sites probably provided better physical cover for moose than untreated sites. We suspect that a combination of good cover and at least adequate food availability makes older treated sites attractive to moose; however, analyses of browse availability data are not complete. In general, these older regenerating clearcuts received greater use by moose than younger sites regardless of treatment, and sites treated 7-10 years previously received the greatest use overall.

Effects on Food Availability for Moose

In 1993, browse availability and utilization were measured on 12 clearcuts (6 treatment and 6 control) to determine second-year effects of glyphosate and on 8 sites to complete (a total of 19 older sites) sampling to determine 7-10 year effects. We measured vegetation on 40 permanent plots per site to determine browse availability and use. Data analyses and interpretation are in progress. We are examining effects of treatment on availability of forage species and evaluating these effects relative to forage preference by moose.

All laboratory analyses of the nutritional quality of forages also are complete (380 forage samples). This information will be used with the food availability and utilization data to evaluate effects of glyphosate treatment on diet quality and nutrition of moose. We also collected and analyzed 40 samples of red maple and paper birch twigs in winter 1993 to determine if plants that survive treatment differ in nutritional quality from untreated plants.

Effects on Food Availability for Deer

This part of the project focused on food availability and quality in summer because deer do not use clearcuts in winter in Maine. We measured effects on food availability using 22 clearcuts: 12 to study 2-year effects and 10 to study 7-10 year effects. We primarily measured food availability by forage class rather than by forage species because previous research showed that deer exhibit consistent seasonal shifts in use of forage classes.

The percent coverage of 7 forage classes and a number of selected species was measured using 40 sampling plots per site. Samples of 24 potential forage species were collected from several clearcuts and analyzed for nutritional quality. Forage quality information will be used to evaluate the nutritional significance of changes in the relative availability of forage classes after treatment.

1993 PUBLICATIONS RESULTING FROM RESEARCH SUPPORTED BY THE CFRU

Briggs, R.D. and R.C. Lemin, Jr. *in press.* Early response of balsam fir *(Abies balsamea* (L.) Mill.) to precommercial thinning. I. Relationship to soil drainage class. Soil Sci. Soc. of Am. J.

Briggs, R.D., R.C. Lemin, Jr., and J.W. Hornbeck. *in press.* Impacts of precommercial thinning (PCT) soil solution chemistry, p. 260. *In;* R.D. Briggs and W.B. Krohn (eds.), Proc. 1993 Joint Annual Meeting of NESAF and MCTWS, Portland, ME, March 3-5. Maine Agric. For. Expt. Sta. Misc. Rept. 382. 289 p.

Briggs, R.D., R.C. Lemin, Jr., and J.D. Pitcheralle. *in press.* Influence of site quality on balsam fir volume increment following precommercial thinning, p. 33. *In:* R.D. Briggs and W.B. Krohn (eds.), Proc. 1993 Joint Annual Meeting of NESAF and MCTWS, Portland, ME, March 3-5. Maine Agric. For. Expt. Sta. Misc. Rept. 382. 289 p.

Eysteinsson, T., M.S. Greenwood, and J. Weber. 1993. Management of a prototype indoor orchard for accelerated breeding of larch. Maine Agric. For. Expt. Sta. Misc. Rept. 377. 18 pp.

Fajvan, M.A. and R.S. Seymour. 1993. Canopy stratification, age structure, and development of multicohort stands of eastern white pine, eastern hemlock, and red spruce. Can. J. For. Res. 23:1799-1809.

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Ren, Y., W.D. Ostrofsky, and R.K. Shepard. *in press.* Application of papermill sludge ash to forest land: Early effects on vegetation and soil microbes, p. 262. *In:* R.D. Briggs and W.B. Krohn (eds.), Proc. 1993 Joint Annual Meeting of NESAF and MCTWS, Portland, ME, March 3-5. Maine Agric. For. Expt. Sta. Misc. Rept. 382. 289 p.

Schaertl G.R. and M.L. McCormack, Jr. 1993. Crown reduction of selected brush and conifer species to Glyphosate herbicide and POEA surfactant rates, p. 85-86. *In:* Proceedings of Northeastern Weed Science Society Annual Meeting. Vol. 47. January 7, Baltimore, MD. (Abstract).

Seymour, R.S. 1993. Plantations or natural stands? Options and tradeoffs for high-yield silviculture, p. 16-32. *In:* R.D. Briggs, and W.B. Krohn, (eds.) Proc. 1993 Joint Annual Meeting of NESAF and MCTWS, Portland, ME, March 3-5. Maine Agric. For. Expt. Sta. Misc. Rept. 382. 289 p.

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ADDITIONAL TECHNOLOGY TRANSFER ACTIVITIES BY CFRU PERSONNEL

Briggs, R.D. Forestry research: A continuing commitment to Maine's forests. Poster presented at the Millinocket Sportsman Show, Millinocket, ME. October 9-10, 1992.

—. Evaluating site productivity. Lecture presented to FTY 508- The Industrial Spruce-Fir Ecosystem. Orono, ME. October 19, 1992.

—. Harvesting impacts on a forested ecosystem - The Weymouth Point Study. Presented at Summer Camp Field Tour at the Weymouth Point Watershed. May 19, 1993.

-------- . Marking guidelines for selection harvests. Presented at Bowater Timberlands Staff Meeting, Millinocket, ME. June 4, 1993.

-------- . Site classification for spruce and fir in Maine. Presented at CFRU Field Tour, Austin Pond, ME. Sept. 10, 1993.

Briggs, R.D., I.J. Fernandez, and J. Simmons. Evaluating gradients of forest nutrient utilization and trace metals within and among climatic regions across Maine. Presented at USFS Meeting "An Overview of Some Long-term Forestry Research in Maine." Orono, ME. March 22, 1993.

Briggs, R.D., R.C. Lemin, Jr. and J.W. Hornbeck. The Weymouth Point Clearcut Watershed Study. II. Precommercial thinning. Poster presented at Silvicon. Fredericton, NB, Canada. Feb. 18-19, 1993.

Briggs, R.D., R.C. Lemin, Jr. and J.W. Hornbeck. Effects of precommercial thinning and drainage class on soil solution chemistry. Poster presented at NESAF Annual Meeting, Portland ME. March 3-5, 1993.

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Carter, K.K. Growth of young black spruce family test plantations in Maine. Communications for industry newsletters. April 1993.

-------- . University of Maine study of 3 black spruce plantations provides information on growth rates, genetic variation in growth. GNP News, Bowater newsletter. May 1993.

Carter, K.K. Forest genetics applications. Presentation to Ontario Advanced Forestry Program, Lakehead University, Thunder Bay, Ontario, Canada. July 19-21, 1993.

---------. Northern Forest Genetics Assoc., University of Minnesota. St. Paul, MN. July 27-29, 1993.

Greenwood, M.S. Field visit Scott Paper Company. May, 1993.

---------. Is there a trade-off between intensive forest management and environmental concerns? Communications for industry newsletters. July 1993.

---------. Canadian Tree Improvement Association, Fredericton, NB, Canada. August 1993.

---------. Visit of INRA Scientist, from Orleans, France. August 27-September 1, 1993.

McCormack, Jr., M.L. Silvicultural employment of herbicide technology. Presentation to FTY 508. Orono, ME. October 1, 1992.

—. Field trip for FTY 508. Austin Pond Study. Site, Bald Mountain Township, ME. October 2, 1992.

—. Multiple use of forest resources in Europe. Presentation to FTY 460. Orono, ME. October 5, 1992.

—. Reductions in herbicide use for forest vegetation management. Invited Symposium Paper, Annual Meeting, Northeastern Weed Science Society. Baltimore, MD. January 6, 1993.

—. Forestry herbicide use in northeastern North America. 14th Annual Vegetation Management Conference, Sacramento, CA. January 13, 1993.

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—. Virgin forests of eastern Europe. Seminar, Orono, ME. February 26, 1993.

—. Herbicide uses in forestry. A briefing presented to congressional members and staff hosted by Responsible Industry for a Sound Environment, Washington, DC. March 24-25, 1993.

McCormack, Jr., M.L. Ontario Advanced Forestry Program, Lakehead University, Thunder Bay, Ontario, Canada. May 1-5, 1993.

—. Presentation to Summer Camp, Acadia National Park, Mount Desert Island, ME. May 14, 1993.

—. Participant in Workshop, International Energy Agency/Bio-Energy hosted by Forestry Canada, Fredericton, NB, Canada. May 21-22, 1993.

—. Radio talk/call in, WERU, Blue Hill, ME. August 6, 1993.

—. Tree improvement program in an established seed orchard. Grand Canadian National "Rendez-vous 93". Lennoxville (Quebec) Canada. August 13-14, 1993.

--------. An overview of the industry and techniques. Mechanical Wood Harvesting Symposium, University of Maine at Presque Isle, ME. August 19, 1993.

--------. CFRU Annual Advisory Committee Field Meeting, Austin Pond Study Site, Bald Mountain Township, ME. September 10, 1993.

Ostrofsky, WD. What's ahead for Maine's hardwood forest resource. Symposium program co-chair and session moderator. Augusta, Maine. October 20, 1992.

—. Establishing research priorities. Presentation to FTY 521. Univ. Maine, Orono, ME. January 21, 1993.

—. Current research on forest land spreading of papermill sludge ash. Northern Forest Forum, Caribou, ME. February 8, 1993.

—. Rating the health of red spruce in the Northeast. Communications for industry newsletters. March 1993.

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—. Impact of harvesting on ecological factors affecting stand health and quality. Vermont Workshop - Silviculture for Loggers. Island Falls, VT. April 28, 1993.

Ostrofsky, W.D. Forest land spreading of papermill sludge, sludge ash, and wood and bark ash residuals - an industry technical review. Meeting coordinator, moderator, and participant. Bangor, ME. May 6, 1993.

---------. Evaluation and identification of hazard trees. Workshop presentation. Management and identification of hazard trees and application of current OSHA logging standards to harvesting operations. Orono, ME. September 14, 1993.

Ren, Y, W.D. Ostrofsky, and R.K. Shepard. Application of papermill sludge ash to forest land: Early effects on vegetation and soil microbes. Poster presentation. Winter meeting, New England SAF, Portland ME. March 3-5, 1993.

Schaertl G.R., and M.L. McCormack, Jr. Crown reduction of selected brush and conifer species to Glyphosate herbicide and POEA surfactant rates. Northeastern Weed Science Society Annual Meeting. Baltimore, MD. January 7, 1993.

Servello, F. Softwood release with herbicides: enhancing moose habitat? Presentation to NESAF and MCTWS. Portland, ME., March 3-5, 1993.

. Poster Presentation Northeast Fish and Wild life Conference, Atlantic City, NJ. April 19-21, 1993.

—. Effects of herbicide on moose activity in clearcuts. Communications for industry newsletters. May 1993.

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—. Scott Paper Co., Forest Management Tour. August 24, 1993.

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--------. High-yield silviculture options. Presentation to NESAF Annual Meeting, Portland ME. March 4, 1993.

—. Fraser, Ltd. Field tour participant. March 9, 1993.

Seymour, R.S. New forestry and biodiversity. Presentation to: Downeast RC&D, Ellsworth, ME. April 17, 1993.

—. Field tour organizer and participant. Maine Div. SAF Field Tbur, Wytopitlock, ME. April 29, 1993.

—. Critique of growth and yield modelling in New Brunswick. Presentation to: NB-FRAC, Fredericton, NB, Canada. May 14, 1993.

—. CFRU Silviculture Tbur - Europe. June 2-15, 1993.

—. A review of growth and yield research needs and application. Presentation to Champion Int. Corp., Bucksport, ME. June 23, 1993.

—. New forestry and high-yield silviculture. Discussion Leader, International Paper Co., Staff Meeting, Livermore Falls, ME. July 29, 1993.

Seymour, R.S. What is the cheapest way to grow industrial wood -- Plantations, precommercial thinning of natural stands, or extensive silviculture? Communications for industry newsletters. September 1993.

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Vera, C.J. and F.A. Servello. Effects of land spreading papermill sludge in forestland on wildlife populations. Presentation at Industry Technical Review of Forest land spreading of papermill sludge, sludge ash, wood and bark. Bangor, ME. May 6, 1993.

COOPERATIVE FORESTRY RESEARCH UNIT ADVISORY COMMITTEE

1993 Membership

The CFRU Advisory Committee sets priorities and reviews proposals for the Cooperative Forestry Research Unit. Members active during all, or part, of 1993 were

Everett Deschenes, Fraser, Inc. (Chair)
Si Balch, Boise-Cascade Corporation (Vice Chair)
Thomas J. Colgan, Forestry Manager, Scott Paper Company (Financial Officer)
Thomas A. Morrison, Maine Bureau of Public Lands (Member at Large)
G. Bruce Wiersma, Dean, College of Natural Resources, Forestry and Agriculture
John Cashwell, Seven Islands Land Company
Edward Chase, Chase Tree Farm
Anthony Filauro, Great Northern Paper
Robert Frank, USDA Forest Service
Dennis Gingles, International Paper Company
Russ Hewett, Pride Manufacturing Company
Peter Ludwig, Champion International Corporation
Ronald Mallett, Maine Power Services
Phil Sullivan, J.D. Irving, Limited
John D. Stowell, Timberlands, Inc.
Peter Triandafillou, James River Timber Corporation

CFRU STAFF (September 30, 1993)

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William D. Ostrofsky, Associate Research Professor of Forest Resources (CFRU Leader)
Maxwell L. McCormack, Jr., Research Professor of Forest Resources Russell D. Briggs,
Associate Research Professor of Forest Resources

Professional Staff

Ronald C. Lemin, Jr., Assistant Scientist
Peter Caron, Research Associate Richard J.
Dionne, Research Associate Eleanor G.
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Cooperating Professors

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B. Krohn, Professor of Wildlife (CFWRU Leader) Robert K.
Shepard, Professor of Forest Resources Katherine K. Carter,
Associate Professor of Forest Resources Robert S. Seymour,
Associate Professor of Forest Resources Frederick Servello,
Assistant Professor of Wildlife

CFRU COOPERATORS 1993

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Field Timberlands
Finestkind Tree Farms
Fraser, Inc.
Great Northern Paper, Inc.-Bowater
Hardwood Products Company
Huber, J.M. Corporation
International Paper Company
Irland Group, The
Irving, J.D., Ltd.
Isaacson Lumber Company
James River Timber Corporation
Knight Tree Farm
LandVest
Madden, F.A., Inc.
Maine Bureau of Public Lands
Maine Christmas Tree Association
Maine Power Services
Moosehead Manufacturing Company
Peavey Manufacturing Company
Penley Corporation
Prentiss & Carlisle
Pride Manufacturing Company
Resource Conservation Services, Inc.
Robbins Lumber Company
Ste. Aurelie Timberlands Co., Ltd.
Saunders Brothers
Scott Paper Company
Seven Islands Land Company
Sew-all, James W. Company
Smith Bros. Associates
Timberlands Corporation
Tbtman, General Clayton O.
Western Maine Nurseries

OTHER ORGANIZATIONS PROVIDING SUPPORT FOR CFRU PROJECTS

DowElanco
Maine Agricultural & Forest Experiment Station
Maine Forest Service
Mclntire-Stennis
Monsanto Agricultural Products Company
USDA Northeastern Forest Experiment Station
USDA State & Private Forestry

APPENDIX

Terminology

SCIENTIFIC NAME	COMMON NAME
Abies balsamea (L.) Mill.	Balsam fir
Abies spp.	Fir
Acer rubrum L.	Red maple
Acer saccharum Marsh.	Sugar maple
Betula alleghaniensis Britton	Yellow birch
Betula papyrifera Marsh.	Paper birch
Fagus grandifolia Ehrh.	American beech
Fraxinus americana L.	White ash
Larix decidua Mill.	European larch
Larix laricina (Du Roi) K. Koch	Tamarack
Larix leptolepis (Sieb. & Zucc.) Gord.	Japanese larch
Larix spp.	Larch
Picea abies (L.) Karst.	Norway spruce
Picea mariana (Mill.) B.S.P.	Black spruce
Picea rubens Sarg.	Red spruce
Picea spp.	Spruce
Pinus strobus L.	White pine
Pinus resinosa Ait.	Red pine
Pinus spp.	Pine
Populus spp.	Aspen
Rubus idaeus L.	Common red raspberry
Tsuga canadensis (L.) Carr.	Hemlock
Aloes alces L.	Moose
Odocoileus virginianus L.	White-tailed deer